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Trends in Work-Related Musculoskeletal Disorder Reports by Year, Type, and Industrial Sector: A Capture-Recapture Analysis

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Background *Musculoskeletal disorders (MSD) are thought to be declining based on Bureau of Labor Statistics survey data, but there is also evidence of MSD under-reporting, raising the possibility of contrary trends. The magnitude of MSD under-reporting over time, and its industry distribution have not been adequately described.*
Methods *Capture-recapture analysis of 7 years of Connecticut MSD (1995–2001), utilizing Workers' Compensation and physician reporting data was performed.*
Results *Only 5.5%–7.9% of MSD cases appear to be reported to Workers Compensation annually. The capture-recapture estimated average annual rate for upper-extremity MSD was 133.1 per 10,000 employed persons, far above BLS rates. By industry, Manufacturing, State Government, and the Finance/Insurance/Real Estate sectors all had significantly higher MSD rates than Wholesale/Retail Trade.*
Conclusions *Upper-extremity MSD appears to be significantly under-reported, and rates are not decreasing over time. Capture-recapture methods provide an improved surveillance method for monitoring temporal trends in injury rates.* Am. J. Ind. Med. 48:40–49, 2005. © *2005 Wiley-Liss, Inc.*

KEY WORDS: cumulative trauma disorders; epidemiology; prevalence; workers' compensation; MSD; under-reporting

BACKGROUND

Work-related musculoskeletal disorders (MSD) comprise well over half of all reported occupational illnesses [OSHA, 2002]. The relatively high prevalence of MSDs motivates an on-going scientific and political debate on the necessity for workplace ergonomic regulations at both the state and federal levels [Hadler, 2000; Punnett, 2000]. Central areas of controversy are the absolute magnitude of the MSD problem, and the direction of recent temporal trends in MSD incidence. The observed rates of MSD and repetitive trauma have been seen to decline in recent years [NIOSH, 2004]. Noting this trend, some authors have stated that there is not a need for ergonomics regulations, because market forces (based on the cost to business of injury compensation) have resulted in effective voluntary ergonomic programs that have reduced the overall magnitude of the problem [Hahn, 1999; Mugno, 2002].

There is, however, evidence that Worker's Compensation reports by themselves may underestimate the magnitude of the overall MSD problem. For example, the annual Federal Bureau of Labor Statistics (BLS) survey of injuries in US

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work establishments routinely reports MSD incidence rates much higher than rates based on comparable Workers' Compensation data [Morse et al., 2004]. Survey research at individual worksites also typically demonstrates higher rates of MSD than those being captured by the local Worker's Compensation system [Fine et al., 1986; Silverstein et al., 1997].

Using a variety of methodologies, a number of more formal scientific studies of MSD under-reporting have been recently conducted [Biddle et al., 1998; Morse et al., 1998, 2001; Herbert et al., 1999; Pransky et al., 1999; Azaroff et al., 2002; Rosenman et al., 2000]. These provide evidence that MSD under-reporting can be substantial, and may represent a general phenomenon in US workplaces [Azaroff et al., 2002]. If so, then observed patterns of increase or declines in Workers' Compensation or BLS MSD injury rates may have significant temporal variations that are simply based on differential injury reporting trends. Since temporal trends in Workers Compensation and BLS MSD injury rates have a significant impact on social policy (i.e., if MSD rates are declining there is less perceived need for ergonomics regulation), it is important to develop methods to accurately define the actual rates of MSD on a population basis, and also to develop unbiased measurements for temporal trends in MSD over time. This study addresses this key question using epidemiologic capture-recapture methodology.

Capture-recapture analysis methodology provides estimates of the number of unreported cases of a disease by comparing the number of case reports to two different data collection systems (in this study, Workers' Compensation first reports of injury and physician reports). It provides an epidemiologic method for estimating the extent of incomplete ascertainment of cases on a population level [Hook and Regal, 1992a,b; Maizlish et al., 1995; Cormack et al., 2000; Morse et al., 2001]. This study provides a capture-recapture analysis of MSD data for the State of Connecticut for the years 1995–2001. Population based estimates of MSD rates, and their recent 7-year temporal trends are presented and compared to standard OSHA-Bureau of Labor Statistics survey data and Connecticut Workers' Compensation reports.

METHODS

Source Datasets

A general description of capture-recapture methods in epidemiology and their assumptions, as well as a description of the source datasets for this study are described in previous reports [Morse et al., 2001; Morse and Kenta-Bibi, 2002]. Briefly, data was compiled from two separate sources: the electronic data records of the Connecticut Workers' Compensation First Report of Injury (FRI) system, and physician reports to the Connecticut Departments of Labor and Public Health Occupational Disease Surveillance System (ODSS). Both data systems are legally mandated in Connecticut. The Workers' Compensation database of all injuries and illnesses was initially queried to obtain all reports that might be occupational illness, even if misclassified (i.e., all Workers' Compensation reports that involve the upper extremity or other body areas, strains, sprains, and any references to cumulative or repetitive injuries) in order to minimize false negatives. This large database was then reviewed record-by-record to eliminate acute injuries (including all lower back cases and upper extremity cases that were clearly acute in nature) to abstract MSD that were chronic/cumulative. The FRI database had some gradual administrative changes over the period as insurers moved from paper submissions to electronic submissions. This may have had some impact on the submission of non-lost time injuries that are not required to be reported since it made it simpler to delete those reports.

Databases were combined for the years 1995–2001, and compared to the original larger databases to ensure that definitions of included and excluded cases (i.e., acute vs. chronic, upper extremity vs. other regions), and coding for type of MSD were consistent for all years. ODSS includes both lost-time and non-lost work time cases, being based on physician diagnosis. The CT WC Commission, on the other hand formally requires that cases that involve either at least one day of lost or restricted duty be reported. However in practice, many employers/insurers submit all claims (including non-lost-time and non-restricted duty) even though it is not required. Both source datasets therefore include a mixture of all types of cases. The exact relative difference in the proportions of different types of cases are unknown, and such differences may decrease the probability of matching somewhat; however the Workers' Compensation reports are a much larger data file, so this type of potential bias should not have a major impact.

MSD Case Definition and Coding

We grouped cases in this study into three broad categories of subacute-onset upper-extremity MSDs:

- Peripheral Neuropathies, ICD9-CM 354.0-354.9. This includes Carpal Tunnel Syndrome and Cubital Tunnel Syndrome.
- Tendonitis, Epicondylitis. ICD9-CM 726.0-727.9. This includes tendonitis, tenosynovitis, De Quervain's Tenosynovitis, Ganglion cysts, Trigger Digit, and Medial and Lateral Epicondylitis
- All Other MSDs. ICD-9CM 443.0, ICD9-CM 723.0, 840.0-842.19; Includes Hand-Arm Vibration Syndrome, Bursitis, Rotator Cuff Injuries, Thoracic Outlet Syndrome, Chronic Joint Strains and Muscle Pain/Inflammation

The diagnostic coding for cases appearing in both databases or in the ODSS alone was based on the diagnosing physician's diagnosis from the ODSS survey. The WC dataset has a number of data fields on which a diagnosis could be based. These included a text name of injury variable, a description of injury variable, and a cause of injury variable. These descriptions and codes were reviewed by the lead author, who assigned them to the above categories of disease. Categorization was also performed independently by the second author (an occupational physician and epidemiologist) in order to ensure coding accuracy.

For multiple conditions, the most serious condition or best-defined condition was utilized: for example, a condition that was described as including pain, tendonitis, and Carpal Tunnel Syndrome was coded as Carpal Tunnel Syndrome.

Cases were evaluated in detail to eliminate duplicate entries within a database and to determine matches across the two databases. Conditions that were reported twice to Workers' Compensation (such as across 2 years), or reported by two different physicians in the ODSS reports were reduced to a single report. If it appeared that the reports were for two separate conditions in the same individual they were retained. Matched cases with dates that differed in the two databases were coded with the workers' compensation date.

Possible matches across databases for the capture-recapture analysis were defined inclusively to reduce false negative matches. For example, a case that was reported by a physician as Carpal Tunnel Syndrome but reported by the employer as pain or tendonitis was regarded as a match as long as it was for the same individual in the same general time period. This method is the most conservative since it reduces the estimates of un-captured cases, and resulting prevalence estimates. In general, the process of identifying matches for individuals across databases was quite accurate since detailed individual identifiers were available in both databases, including name, address, phone number, birth date, and social security number. Reports for both the WC and ODSS databases were required by state statute and were exempt from laws restricting access to personal identifiers. A confidentiality agreement was in place between the CT Department of Public Health and the University of Connecticut School of Medicine, which allowed access to the data.

Connecticut Industry Data

BLS survey data was obtained through the CT Labor Department, and is based on the annual survey conducted nationally [Bureau of Labor Statistics, 2002], and in CT includes public employees. The CT BLS survey is a stratified population-based survey of employers, and does not utilize workers' compensation records. Connecticut employment data was also obtained from the CT Labor Department, using the same definitions as is used in the BLS survey (i.e., adjusted for full-time equivalent workers).

Coding for industrial classification was performed by the CT Department of Labor, utilizing the same Industry coding format as is employed for the annual Conn-OSHA/BLS survey. Industry Sectors and their 3-digit Standard Industrial Coding (SIC) equivalent codes [OMB, 1987] were as follows:

Agriculture, Mining, Construction	011–179
Manufacturing	201–399
Transportation, Utilities	401–497
Wholesale & Retail	501–599
Finance/Insurance	601–679
Services	701–899
Government	911–972

Government workers were further partitioned into State versus Municipal sectors. Federal workers were not captured by the WC system, and were therefore not included in the study.

Statistical Methods

Capture-recapture analysis was used to estimate the number of unreported and total MSD cases. The most important assumption in this study is independence between the two data sources, i.e., the propensity of an individual being captured in one source does not depend on its capture status in the other source. In the event that there is positive association between the two sources, there is relative underestimation of the population size, while overestimation usually follows from negative association [Hook and Regal, 1995a]. Capture-recapture methodology also assumes that the population is closed and homogeneous [Hook and Regal, 1995a,b]. In general, the estimates obtained using this approach are biased but the bias tends to be very small for large population (and sample) sizes. In this study the population is relatively closed by nature of employment and is relatively homogeneous since each individual hypothetically has the same probability of being captured in a particular source. The assumption of independence of the two samples is complex and cannot be completely determined. It is probable that there is a positive association between the two primary data sources since individuals diagnosed by occupational physicians would be more likely to file a claim under workers' compensation as they tend to be more familiar with the system, and workers are more likely to have their physical complaints assessed for work-relatedness, even when treated by non-occupational physicians. However, there are complex inter-relationships for reporting claims involving demographics, such as white collar versus blue collar status, gender, unionization, fear of employer retribution, industry sector and other variables [Morse et al., 2003b]. This makes it difficult to assess whether these capture-recapture estimates are a lower bound or an upper bound of the actual population.

A more extensive discussion of capture-recapture methods for these Connecticut data have been previously published [Morse et al., 2001].

Log-linear modeling, along the lines presented by Cormack [1989] was used to estimate the unreported MSD cases per year. The model used reflects complete independence between the data sources and the year in which they were recorded. This approach represents the number of observed cases (response variable) as Poisson counts and estimates the unreported cases using the method of maximum likelihood estimation (MLE). A similar modeling approach was employed to estimate the unreported cases broken down by industry sector. Chi-square and deviance statistics were used to evaluate overall model significance while Wald and Chi-square statistics were employed to verify significance of individual effects [Agresti, 1996].

In the breakdown of MSD by diagnosis, adjustments were made to account for misclassification of diagnosis in the Workers' Compensation database as well as allowing for the possibility of an individual having more than one condition, since the coding in WC was imprecise. We were able to utilize the information from the matching between the two databases to identify the diagnostic categories that were used in the WC database for the same cases in the ODSS database. The ODSS physician's diagnosis was considered to be the gold standard, and the equivalent diagnostic category in WC for each matched case was tabulated to see the proportion contributed. For example, for all the Carpal Tunnel Syndrome cases in the ODSS, a certain proportion of the matched diagnoses in WC were tendonitis, pain, etc.

The approach used was therefore to weight the estimated total cases by the proportion of observed cases for each type of diagnosis, i.e., $\hat{N}^{(r)} = \hat{N}\hat{p}^{(r)}$, where $\hat{N}^{(r)}$ is the estimated cases under a particular diagnosis, $\hat{N}$ is the estimated total MSD cases, and $\hat{p}^{(r)}$ is the observed proportion of cases under the rth diagnosis (nerve-related, tendon-related, and other MSD) from the two sources. The adjusted standard error obtained by the conditional distribution approach is given by $\text{s.e.}(\hat{N}^{(r)}) = \sqrt{\hat{p}^{(r)}(1-\hat{p}^{(r)})\hat{N} + (\hat{p}^{(r)})^2\hat{V}(\hat{N})}$. The underlying assumption here is that the observed distribution of cases diagnosed is representative of the underlying distribution. This approach is conservative in that it increases the estimated variability as a result of possible misclassification.

Results of the capture-recapture estimates are compared with the annual Bureau of Labor Statistics (BLS) survey that is done in concert with OSHA. This survey is a population-based sample of CT workplaces, stratified by size and type of business. It is conducted independently of the CT Workers' Compensation process, and is not based on recorded WC cases. During the study years, BLS data included a category of ''repetitive trauma'' which is dominated by chronic upper-extremity conditions. A small number of other illnesses caused by chronic exposure such as noise-induced hearing loss are also coded in this category [Bureau of Labor Statistics, 1986]. Analysis utilized Microsoft Excel and Access for Windows (Office 2000 version) for data review, coding, and matching. SAS v. 9.1 was used for statistical analysis.

RESULTS

There were a total of 15,988 unique MSD reports submitted to either Workers' Compensation by employers or to the Occupational Disease Surveillance System by physicians in Connecticut between 1995 and 2001. Table I presents the figures by year that were received only by the ODSS, only by the Workers' Compensation Commission, by both systems (the set of matched cases), and the totals for all reports, adjusting for the cases reported to both systems. There were a total of 6,213 cases reported to the ODSS (row a + c of table), and 10,205 reported to Workers' Compensation (b + c). Only 430 cases were reported to both systems over the 7-year period. Overall, this set of matched cases (c) averaged 4.2% of the Workers' Compensation reports over the entire study

TABLE I. MSD Reports, WC, ODSS, BLS-ConnOSHA, and Estimated Un-Reported MSD Cases, Connecticut, 1995–2001

	1995	1996	1997	1998	1999	2000	2001	Total	Average
a. ODSS only	617	935	891	745	745	1,070	780	5,783	826
b. WC only	867	1,052	874	1,558	1,911	1,954	1,559	9,775	1,396
c. Matches	39	47	52	57	77	98	60	430	61
d. Total of unique cases (a + b + c)	1,523	2,034	1,817	2,360	2,733	3,122	2,399	15,988	2,284
e. Uncaptured	12,523	16,725	14,940	19,405	22,472	25,671	19,726	131,462	18,780
f. Estimated total (d + e)	14,046	18,759	16,757	21,765	25,205	28,793	22,125	147,450	21,064
g. BLS/ConnOSHA	4,220	3,711	3,335	3,398	3,306	3,827	3,220	25,017	3,574
h. CT employment (1,000)	1,520	1,538	1,570	1,597	1,630	1,653	1,572		1,583
i. Rate of MSD (f/h) × 10,000	92.4	122.0	106.7	136.3	154.6	174.2	140.7		133.1
j. % Reported to WC (b/f)	6.5%	5.9%	5.5%	7.4%	7.9%	7.1%	7.3%		6.9%

ODSS, occupational disease surveillance system (physician reports); WC, workers' compensation first report of injury; BLS/Conn-OSHA, upper-extremity repetitive trauma estimates from the Bureau of Labor Statistics annual survey: CT employment in 1,000's.

period. Total annual workers' compensation reports, as a percentage of total estimated MSD cases (j) averaged 6.9% and ranged from 5.5% to 7.9% of the WC reports over the 7-year period. This percentage of reports to workers' compensation was significantly higher over the last 4 years compared to the first 3 years. The average 7-year upper-extremity MSD estimated rate (i) based on capture-recapture in Connecticut was 133.1 per 10,000 employed persons per year (95% CI 123–143 per 10,000).

Table I also presents estimates of upper-extremity ''repetitive trauma'' in the state of Connecticut based upon the Bureau of Labor Statistics/Connecticut OSHA (BLS) annual employer survey data for the same years (g). BLS figures for MSD were trending lower over the first 3 years, then held fairly stable (with the exception of an increase in 2000). The downward trend in BLS figures was present in earlier years, declining from 5,596 in 1993 to 4,482 in 1994 (not in table; we do not have comparable figures available for the other reporting systems). The workers' compensation reports were, in general, trending higher (also reflected in the unique cases), except for declines in 1997 and 2001. All systems showed peaks in 2000. Total Connecticut employment trended higher until 2000, then declined in 2001.

Estimates for un-captured (unreported) cases were made (row e). There were an estimated total of 131,462 unreported cases of MSD over the 7-year period. The set of combined reported and estimated unreported cases was 147,450 (95% CI = 134,045–160,246) for the 7-year period. On an annual basis, there was an estimated average of 21,000 MSD cases per year, compared to the approximately 1,500 reported to workers' compensation and 3,500 estimated by BLS.

Trends in rates by year were somewhat different for the different data sources (Figs. 1 and 2, Table I). BLS showed a slight downward trend from 1995 to 1997, then mostly steady rates. Workers' compensation reports were generally increasing, with a decrease in 2001 from 2000. ODSS had a mixed pattern, with an early increase followed by a decrease, and then steady numbers except for a sharp increase in 2000. Estimates based on the capture-recapture method were complex but the general trend was higher (with rates in the last 4 years mostly significantly higher than the first 3 years). By individual year, there was an early up and down trend, then increasing rates in the last 4 years with a decline in 2001.

For the 7 year dataset, MSD were analyzed further by diagnostic category (Table II). Nerve disorders accounted for just over one-quarter of the cases, approximately the same as for tendon disorders. There were over 4,000 reported cases for both categories of MSD, while the estimates for total cases was nearly 10-fold greater (this latter estimate by definition includes all reported cases). ''Other'' cases had over 7,000 observed cases, and an estimated 65,000 cases in total for the 7 years combined. Matches (based on the ODSS categories) were more common for the more serious nerve related disorders (11.4% of ODSS nerve cases) than tendon-related disorders (6.2%), which in turn were more common than for ''other'' (3.7%).

Combined MSD cases of all types over the 7 years were broken down by major industrial sector (Table III). Manufacturing had by far the largest overall number, both in terms of reported cases as well as estimated totals. The estimated rate for manufacturing based on estimates for total cases was 250 per 10,000 employees, which was, however, less than the rate for state government (328 per 10,000). The Transportation/Utilities sector estimate had a very low number of matches, and should be considered statistically unstable. State Government, Manufacturing, and the Finance/Insurance/Real Estate sectors were all significantly higher than the lowest sector (Wholesale/Retail trade). State government

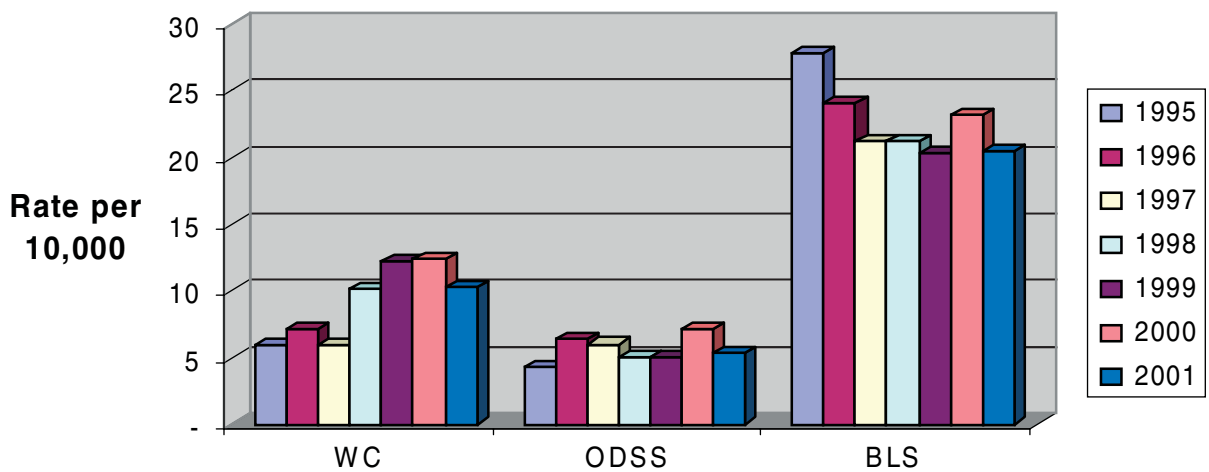

FIGURE 1. Upper extremity MSD rate by year and data source, Connecticut, 1995–2001. Note: Rate is MSD per 10,000 employed persons. Abbreviations: WC, Workers' compensation; ODSS, CT Occupational Disease Surveillance System; BLS, CT Bureau of Labor Statistics Annual Surveys.

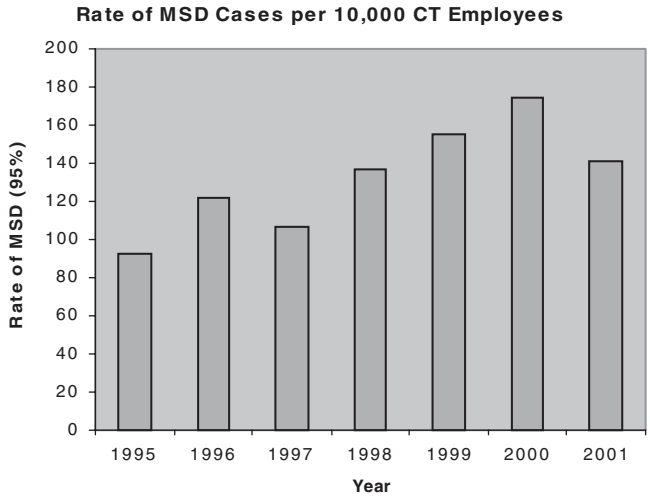

FIGURE 2. Annual rate of MSD cases per 10,000 CT employees, capture-recapture estimates.

had the highest proportion of matches compared to the overall estimate (9.1%), followed by Finance/Insurance (7.7%), Construction/Agriculture/Mining (7.2%), and the Services sector (7.0%). It should be noted that the agricultural and mining sectors are quite small in Connecticut—construction accounts for approximately 75% of employment and MSD in that grouping.

The total number of unique reported cases (WC and ODSS) was strongly related to overall CT employment levels ($R^2 = 0.87$), however log-linear analysis revealed that employment levels did not significantly affect rates other than by increasing the denominator (i.e., that more workers are at risk when there is higher employment). The number of ODSS reports (the smaller, and therefore somewhat more variable number) affected the projected rates somewhat more than the number of workers' compensation reports.

DISCUSSION

Our study has found evidence of extensive under-reporting of work-related upper-extremity MSD, with less than 10% reported to Workers Compensation in the different years. Estimates of MSD based on the BLS survey also appear to under-count MSD, and trends seem generally to be stable or increasing in contrast to the overall declines indicated by BLS surveys. At any rate, there is no evidence for a decrease in MSD in CT during the recent 7 year time span covered by the study. Estimated MSD rates were significantly higher in State Government, Manufacturing, and Finance/Insurance/Real Estate sectors in comparison to the trade sector.

Study Limitations

Overall, the application of capture-recapture analysis to the Connecticut WC and ODSS datasets is subject to a number of limitations, which have been previously reviewed [Morse et al., 2001]. With respect to comparability of case diagnosis in the source datasets, MSD definitions are very similar, but not completely identical. WC data can lack precise diagnostic information for cases. We attempted to compensate for this potential bias by using broad diagnostic subgroups for analysis. This was possible because the Workers' Compensation data includes text fields for the name of the injury or illness, for the part of the body affected, a text field for describing the details of the injury, and a text field describing the mechanism of the injury. Thus at the broader, aggregate level, we were able to achieve better comparability. These broader classifications are considered to improve diagnostic validity for prevalence surveys [Colditz et al., 1986; Cox and Iachan, 1987].

To maximize matching precision, we employed both electronic and manual matching techniques. We also increased the likelihood of detecting matches (and minimizing our estimates) by screening cases across adjacent years of the two databases. Capture-recapture analysis assumes a reference population closed to losses or entries during the study period. It is likely that some MSD cases were treated in and reported to jurisdictions other than Connecticut. Also, some MSD cases (for example seasonal agricultural workers) may have migrated out of the state. Further, studies of agricultural workers do indicate that non-reporting of injuries

TABLE II. Capture-Recapture Estimates for Total MSD by Type, With 95% Confidence Intervals, 1995–2001 Combined, CT

Category	ICD9-CM	Obs	Prop.	Est.	SE	LB	UB
Peripheral neuropathies	354.0–354.9	4,309	0.27	39,740	1,815	36,183	43,297
Tendonitis/epicondylitis	726.0–727.9	4,503	0.28	41,529	1,896	37,813	45,246
All other MSDs	443.0, 723.0, 840.0–842.19	7,176	0.45	66,181	3,015	60,271	72,091

Obs, observed cases reported either to the WC or ODSS systems; Prop., proportion of total MSD; Est., capture-recapture estimate of total population cases; SE, standard error of estimate; LB, lower bound of 95% confidence interval; UB, upper bound 95% confidence interval.

TABLE III. Capture-Recapture Estimates for MSD in Connecticut by Industry, Combined Data for 1995–2001

				Estimated MSD cases				Average annual rates		
Industry sector	Match	ODSS only	WC only	Total	Lower 95% CI	Upper 95% CI	Percent reported	Rate	Lower 95% CI	Upper 95% CI
Ag/Mine/Cons	19	219	405	5,848	5,234	6,545	7.2%	106	95	119
Manufacturing	163	2,026	2,974	46,959	42,879	51,481	6.7%	250	228	274
Trans/utilities	7	263	474	6,767			7.1%	124		
Whole/retail	91	1,018	1,259	21,538	19,594	23,701	6.3%	86	78	94
Fin/Ins/RE	26	386	884	11,788	10,666	13,043	7.7%	120	109	133
Services	72	1,092	1,841	27,332	24,900	30,033	7.0%	76	69	83
Municipal[a]	22	391	496	8,268	7,446	9,193	6.3%	96	86	107
State of CT[a]	28	264	1,279	14,289	12,956	15,778	9.1%	328	297	362

Rate is annual rate per 10,000 employees.

Ag/Mine/Cons, Agriculture, mining, and construction, with construction being the major component in CT; Fin/Ins/RE, finance, insurance, and real estate; WC, workers' compensation; ODSS, CT occupational disease surveillance system.

[a]State and Municipal governmental employees manually grouped; Federal employees excluded from study.

Confidence interval estimates are not made for Trans/Utilities due to the low number of matches, leading to unstable estimates.

is common [Holmberg et al., 2002]. We cannot estimate the effect of these potential biases, but we do not believe they are likely to represent a large study effect, given the total 7-year study sample size, and the fact that the industries most likely affected (agriculture) are comparatively small in Connecticut.

With reference to the assumption of independent source samples, there is a likely positive correlation between WC and ODSS cases. Physician diagnosed MSD cases are more likely to be reported to Workers' Compensation insurers. The effect of this positive correlation between source samples should, however, result in an under-estimate of un-captured cases and therefore more conservative prevalence estimates [Hook and Regal, 1995a].

It should be noted that the presented confidence intervals in capture-recapture methods only apply to the potential sampling error, and do not adjust for violations of underlying assumptions such as correlations in probability of capture between databases or variable catchability within databases [Hook and Regal, 1993, 1995b], both of which are likely in this (and most other) capture-recapture studies. While the precision of the estimates should therefore be viewed with caution, the method allows an estimate of under-reporting that is not available by other current achievable means.

Recently, there has been increased attention to the methodological difficulties inherent when capture-recapture methodology is applied in epidemiologic settings. For example, Cormack et al. have emphasized the error engendered by samples severely restricted in overlap (matching cases) and emphasized the necessity for complex modeling to produce reliable estimates to evaluate the adequacy of multi-sample estimation against a gold standard [Cormack, 1999; Cormack et al., 2000]. While this latter study was too limited in size to allow any firm conclusions, it does emphasize that capture-recapture estimation studies require particular attention to bias estimation and to statistical methods, which has been emphasized previously [Hook and Regal, 1995a]. As with any epidemiologic study, there is also the need for external validation of study results and replication via epidemiologic studies with differing methodology. In assessing the overall direction of our own potential study biases, we feel that the current estimates presented are likely best considered as an upper bound for the true population values.

Under-Reporting

There is considerable evidence based on research studies with differing study designs that MSD are in general, under-reported, and that WC data does not accurately reflect prevailing MSD occurrence rates [Lipscomb et al., 1997; Biddle et al., 1998; Morse et al., 1998, 2001, 2003; Herbert et al., 1999, Pransky et al., 1999; Rosenman et al., 2000]. In a review of the literature and using a comprehensive set of data sources, Leigh et al. [2004] estimate that the BLS survey misses a minimum of 24.8% of occupational injuries (which are less likely to be under-reported than illnesses) due to non-coverage of certain types of employees, and misses 33%–67% when under-reporting is taken into account.

To date few studies have attempted to address temporal trends in overall MSD rates, and to relate these to the magnitude of, and trends in, under-reporting. Two key questions are whether the year-to-year variance in under-reporting is sufficient to explain the changes in annual OSHA/BLS MSD rates and whether the phenomenon of under-reporting varies by industrial sector. Our current data indicates that only an estimated 7% of cases of MSD were reported to Workers' Compensation in Connecticut over a 7-year period (ranging from 5.5% to 7.9%), compared to 4.2% that were reported

through the ODSS system. Our estimated total number of CT MSD cases is approximately six times the OSHA/BLS survey number of cases for the same period. While a small fraction of this difference may be explained by variation in case definitions of MSD between the two studies (OSHA/BLS includes a relatively small number of hearing loss cases in its definition of chronic injuries), it is likely that the true number of MSD cases in CT considerably exceeds OSHA/BLS estimates. The OSHA/BLS MSD estimates themselves, in turn exceed the number reported by Worker's Compensation. Also, the lower bound of 95% confidence intervals for the capture-recapture prevalence estimates is higher than the corresponding prevalence estimates based on either WC or BLS data, so in general, the fact that the capture-recapture estimates are higher is unlikely to be due to chance.

Temporal Trends

With respect to temporal trends, there were differences between the capture-recapture estimates and OSHA/BLS survey data. Over the first 3 years, we found fairly flat capture-recapture estimated rates as compared to sharp decreases in BLS rates; during the last 4 years capture-recapture estimation showed generally increasing rates in contrast to fairly flat rates for BLS data (Figs. 1 and 2). During this period, Workers' Compensation rates were generally rising, with a sight decrease in the final study year.

There are comparatively few studies of temporal trends in MSDs. Recently, Mustard et al. [2003] reported on secular reporting trends in total work injuries (not solely limited to MSD) in the Province of Ontario for 1993–1998. The study compared trends in three data sources: two panel surveys in the province of Ontario, Canada, and provincial Workplace Safety and Insurance Board work-related injury and illness compensation claims during the same period. Lost-time compensation claims declined by 28.8% over this 6-year period. Parallel reductions in work-related morbidity ranging from 28.2% to 32.2% were seen in the two independent panel surveys. The results, however, were not adjusted to reflect the bias due to closure of the survey panel to recruitment of new workers or exit of panel members from the workforce due to injury; hence they are not easily interpretable as a traditional longitudinal study would be. The authors believed that demographic trends in employment were unlikely to have affected their data, and focused attention on provincial workplace primary injury prevention practices as a possible explanation of their observed trends.

Industrial Sector

Consistent with previous research findings [Morse et al., 2003], our data confirms that the manufacturing sector has moderately high MSD rates, and because of its size, contributes the largest absolute number of MSD cases. State government had the highest rate for MSD, though it contributed lower overall cases based upon the smaller workforce. Silverstein et al. [1997] found somewhat different patterns, but their major industry analysis included lower back as well as upper extremity cases. They found that construction had the highest rate and insurance the lowest (including non-traumatic back conditions as well as upper extremity), whereas we found both industries to be about in the middle for upper extremity alone.

While there was some variation in under-reporting of MSD by economic sector, this variation was not large. Our results here indicate that manufacturing workers are roughly the same as other industries in relation to the likelihood to report MSD cases; this is in contrast to our prior population based analysis (the CUSP survey) which showed employees in manufacturing were 10 times more likely to report cases of MSD than other industries [Morse et al., 2003]. This earlier study, however, was limited to a single year and a smaller sample size, and the present study did not employ control variables (such as unionization and severity of condition), as these were not available. Overall, our data indicates that MSD under-reporting is a widespread phenomenon in the current Connecticut economy, and not strictly attributable to any one industry segment.

Incidence Rates

Our current 7 year mean capture-recapture estimate for upper-extremity MSD in Connecticut is 133.1 cases per 10,000 employed persons. Previously in 1996, a statewide population-based survey of upper-extremity MSD (the CUSP survey) was performed [Morse et al., 1998; Warren et al., 2000]. This was a random digit dialing telephone interview survey of CT working-age persons and used standard screening questions [Park et al., 1993] previously developed in National Institute for Occupational Safety & Health physical examination field studies. This questionnaire was designed to identify MSD cases with high probability [Baron et al., 1996]. An estimate for the MSD incidence rate was made for the year 1996, which was 78 cases per 10,000 workers (95% CI 58–124/10,000). While this estimate is based on a different methodology, with a potential bias towards underestimation (telephone interview surveys do not capture data for the poorest segment of workers), the estimate it produced is of the same general magnitude as our current ones, and is consistent with the hypothesis of widespread MSD under-reporting.

There are relatively few other population-based surveillance studies of MSD. Tanaka et al. provided US national estimates of the prevalence of both hand-wrist tendonitis and carpal tunnel syndrome based on data from the Occupational Health Supplement Data of the 1988 U.S. National Health

Interview Survey (NHIS-OHS) [Massey et al., 1989; Lalich and Sestito, 1997; Tanaka et al., 2001]. This is an in-person, household interview survey of US working adults. The case definitions and diagnostic groupings employed in this study were comparable to our own. Among the 30,074 survey respondents, 0.46% (95% CI: 0.36, 0.56), reported hand discomfort which was called tendonitis, synovitis, tenosynovitis, deQuervain's disease, epicondylitis, ganglion cyst, or trigger finger, by a medical provider. Some 0.53% of respondents reported having carpal tunnel syndrome in the same period. Also, some 27.8% of tendonitis cases were considered to be work related by the attending medical provider, whereas 52.8% of carpal tunnel cases were considered work-related.

The NHIS-OHS estimates predict an annual rate for hand-wrist tendonitis of 12.8 work-related cases per 10,000 employed persons (95%CI 10.0–15.5/10,000), and for carpal tunnel syndrome 28.0 work-related cases per 10,000 employed persons (95%CI 21.7–34.3/10,000). Projection of these estimates to the population totals for the Connecticut working population for the period 1995–2001 in Connecticut would predict some 14,000 work-related hand-wrist tendonitis cases and 31,000 work-related carpal tunnel cases over the 7-year period (95% confidence intervals for these estimates are 11,080–17,174 cases and 23,986–38,026 cases, respectively). These estimates compare to 40,146 (95% CI 36,547–43,744) work-related hand-wrist tendonitis cases and 42,876 (95%CI 39,034–46,717) work-related carpal tunnel cases estimated from our current study. The time periods and methodologies for the two studies are different, and the estimates themselves also differ; however, both methods suggest that work-related MSD are an order of magnitude larger than those reported to either the WC or OSHA/BLS systems.

In our study, peripheral nerve and tendon-related MSDs both had approximately the same number of estimated cases, while the combination of all other upper-extremity MSDs had comparatively more. However, reporting was better for carpal tunnel syndrome and peripheral neuropathies, and the tendonitis cases: the neurological conditions had the most matches, while the larger residual category of MSDs had the least. This finding is consistent with published data from the CUSP survey that found that the severity of condition was the most prominent factor associated with reporting [Morse et al., 2003]. It is also important to acknowledge that other social factors play an important role in determining rates of reporting, including having a unionized workforce, working in the manufacturing sector, being an hourly (vs. salary) employee, having a personal physician, working for large employers and finally, having less fear of reporting [Oleinick et al., 1995; Pransky et al., 1999; Azaroff et al., 2002; Morse et al., 2003a,b]. These factors all may contribute to the findings above in relation to relative rates of reporting by different industries.

CONCLUSIONS

Our overall findings point to the conclusion that the degree of under-reporting of upper extremity MSD is considerable. Also, with respect to temporal trends, there is not evidence that MSD rates have substantially decreased over a recent 7-year period as is indicated by BLS. These conclusions based on capture-recapture estimation are supported by additional population based studies with different methodologies, hence they have fair external validity. Our data therefore suggests that ordinary Workers' Compensation data (and the BLS surveys) may be insufficient for estimating the magnitude of the work-related MSD. This should not be construed to suggest that Workers' Compensation data has no epidemiologic utility. Clearly it has been used productively in many investigations [Goldsmith, 1998], however the strengths and weaknesses, and the inherent biases of this particular source of data need to be clearly understood to use it effectively.

An important inference from our data is that many injured workers with MSDs, perhaps even the majority, choose not to pursue Workers' Compensation claims, seeking treatment for their injuries on a private basis. They apparently do not inform employers of their condition. This perspective contrasts sharply with the recent assertion there is a ''moral hazard'' from Workers' Compensation insurance that results in application for benefits from workers who do not in fact have work-related MSD, or that employees in high insurance benefit states are less likely to work safely [Baker, 1996; Durbin, 1997]. The bulk of employees with MSDs, however, appear to have no particular wish to enter, much less take advantage of the Connecticut Workers' Compensation insurance system. This phenomenon has important implications for workers with MSD, who may bear the costs of medical treatment on their own [Morse et al., 1998]. There are also potential economic implications for employers: cost shifting from Workers' Compensation to private sector insurers, productivity losses, and increased rates of ''unexplained'' turnover of experienced, trained workers.

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