Title: Capture-Recapture Estimation of Unreported Work-Related Musculoskeletal Disorders in Connecticut

Authors: Timothy Morse, PhD, Charles Dillon, MD, PhD, Nicholas Warren, MAT, ScD, Charles Hall, PhD, and Deborah Hovey, MSW

Departmental Attribution: All but C Hall are from the Division of Occupational & Environmental Medicine, University of Connecticut Health Center; C Hall is from the Department of Community Medicine, University of Connecticut Health Center.

Corresponding Author: Timothy Morse, Division of Occupational & Environmental Medicine, University of Connecticut Health Center, Farmington, CT 06030-6210 (860) 679-4720; FAX: (860) 679-1349; tmorse@nso.uchc.edu

Running Head: Unreported MSD

Support: This research was supported in part by NIOSH grant # RO1 CCR112118-03

Abstract

Background: Estimates of the extent of musculoskeletal disorders (MSD) are usually based upon workers' compensation reports, although recent reports indicate that there may be widespread under-reporting of MSD.

Methods An estimate of the incidence of arm and hand work related MSD was made using capture-recapture analysis of the overlap between state workers' compensation reports and physician reports in Connecticut for 1995. The resulting estimate was compared to a population-based survey of MSD.

Results: There was very small overlap between the two state injury reporting systems: 6.7% of 793 reported workers' compensation cases, or 8% of 661 physician's reports. The estimate for MSD not captured by either system was 13,285, resulting in 14,686 (95% CI 9,733-18,453) total reported and non-reported cases. This compares to an estimate of 13,775 cases (95% CI 8,800-18,800) based on a phone survey.

Conclusions: This analysis points to substantial under-reporting of MSD in Connecticut: estimates of unreported cases exceed those officially reported by a factor of 11:1. The findings have an important bearing on injury prevention programs and policy making.

Key Indexing Terms: Musculoskeletal Disorders; MSD; Cumulative Trauma Disorders, Epidemiology, Prevalence, Workers' Compensation

Introduction

Reported incidence rates for work-related musculoskeletal disorders (WRMSD) not attributable to acute injury increased rapidly in both Connecticut (CT) and the U.S. over the last 17 years, with some decrease over the last three years. These incidence rate estimates derive from U.S. Bureau of Labor Statistics (BLS) surveys (Connecticut Labor Dept., 1981-98, U.S. Bureau of Labor Statistics, 1998, Brogmus, et al, 1996), from analyses of cases reported through the workers' compensation insurance system (Tanaka, et al., 1988, Korrick et al., 1994, Miller, 1994, Ashbury, 1995, Frazier and Loomis, 1996), and from physician reporting or health insurance data analysis (Liss, et al., 1992, Ekberg et al., 1994; English, 1995). Discussions continue regarding the actual extent of such WRMSD: i.e. the degree to which true incidence is different from the number of reported cases. Some studies suggest that WRMSD are in general under-reported (Rosenman, et al, 2000; Fine et al., 1986, Gerr et al., 1991, Kraut, 1994, Maizlish et al., 1995, Oleinick, 1995). The extent of potential under-reporting on the state or national level, if any, has been difficult to establish using traditional methods of looking at workers' compensation data, medical case series, or industry prevalence surveys.

Potential under-reporting of cases affects employers' economic incentives to implement prevention strategies. If musculoskeletal disorders among employed persons are not recognized as work-related and handled through workers' compensation, then employers will not easily be able to estimate the cost effectiveness of safety measures designed to prevent such conditions. Furthermore, under-reporting could impact regulatory and appropriations processes by under-estimating the actual magnitude of the problem faced by both employers and the workforce.

This article estimates the incidence of WRMSD in Connecticut using epidemiologic capture-recapture methodology (Hook and Regal, 1995), a method for estimating total population size based on two independent sub-samples of that population. Our analysis develops WRMSD population estimates by comparing cases reported through the CT Workers' Compensation insurance system to cases identified in the state's physician-based occupational disease and injury reporting system. This methodology has previously been used to estimate the incidence of occupational fatalities (Rossignol, 1994) and local county level carpal tunnel incidence (Maizlish et al., 1995), but has not heretofore been utilized to estimate WRMSD incidence for larger populations.

Methods

Capture-Recapture Methodology

Capture-recapture studies are epidemiologic methods for estimating the extent of incomplete ascertainment using population-based data from two independent, but overlapping sources. The methodology originates in wildlife biology (Seber, 1982) and

demography (El-Khorzaty et al, 1977), and has been adapted in epidemiology to provide population parameter estimates based on two or more incomplete sources; to refine incidence estimates and their upper and lower bounds; and to estimate the completeness of apparently exhaustive surveys (Hook and Regal, 1992, 1993, 1995). Prerequisites to capture-recapture analysis are delineation of two independent samples of the same population using a format permitting accurate identification of all potential overlapping cases between the two samples. The extent of overlap of cases from the two sample sources determines population estimates: low overlap indicates a large total population compared to captured numbers; a high degree of overlap indicates that the two sources comprise a large proportion of the total population, and the number of additional uncaptured cases is few. For capture-recapture analysis, source dependency (non independence of groups sampled) should be avoided. The population studied is assumed to be closed for entries and losses during the defined study period. As with any analytic study, accurate, comparable case definitions must be applied to both groups. The statistical methodology for capture-recapture studies has been extensively described (Hook and Regal, 1993,1995).

Data Sources:

Connecticut Workers' Compensation Insurance Data:

Workers' compensation employer First Report of Injury data for 1995 was made available by the Connecticut Workers' Compensation Commission (WCC). The insurer or a self-insured employer files reports to the Commission either electronically or in paper format. These data include primarily lost-time injuries (cases are required to be reported if they result in lost time or modified duty for one day or more, though some non-lost time cases are also reported by insurers). Reports are based upon employers' definitions and compliance with reporting procedures. Incorrect coding of conditions is potentially problematic since the report may or may not rely on a written physician's diagnosis, although 1) the specific nature of the injury, 2) the part of body affected, 3) a text description of the injury, and 4) the likely cause are all usually recorded. The current data includes all injuries that were classified by nature as cumulative or repetitive trauma of the hand or upper extremity, or that involved specific disease categories that could be hand or arm WRMSD.

State of CT Physician Occupational Disease Surveillance System (ODSS):

All physicians practicing in Connecticut are required to report known or suspected occupational disease cases to the State Departments of Public Health and Labor. WRMSDs not related to a sudden acute injury (i.e. "cumulative trauma disorders") are included in this reporting system. Reports are sent by physicians to the Connecticut Labor Department, coded for industry and occupation, and then forwarded to the Department of Public Health for data entry. An electronic copy of that database for 1992 through 1996 was used for this analysis. This database was reviewed for WRMSDs, using the same criteria as was used for the Workers' Compensation database.

Comparability of Data Sources:

Both source data sets consist primarily of physician diagnosed WRMSD cases. WCC data includes reports from all types of CT physicians. ODSS data, on the other hand, while potentially receiving reports from all types of physicians, in practice has a very large proportion of reports from the state's occupational medicine clinics, industrial medicine facilities, and company-based physicians. CT Workers' Compensation reporting by definition does not include injuries for Federal employees or self-employed persons. These latter cases can occur in the ODSS data, but in practice constitute a very small minority of reports. WCC injury reports by insurers are principally lost-time or restricted duty cases, as CT statute requires only these types of cases to be reported to the state Workers' Compensation Commission, even if medical bills were paid under compensation insurance plans. The ODSS database contains both lost-time and non lost-time cases. To assure comparability between the datasets, we adjusted the ODSS reporting to reflect an estimate of lost time and modified duty cases only, based on reporting estimates from major clinics in the system.

Case Definition and Sample Overlap Determination:

Text describing cases from the two primary study data sources were manually reviewed for diagnostic data, the nature and probable cause of injury and the body part affected. Cases included for the current study were grouped into four broad categories of subacute-onset hand-arm musculoskeletal disorders:

1. Carpal Tunnel Syndrome ICD9-CM 354.0.
2. Tendonitis, Tenosynovitis, Ganglion Cysts ICD9-CM 726.0-727.9.
3. Hand-Arm Vibration Syndrome (HAVS) ICD-9CM 443.0.
4. Muscle Pain/Inflammation ICD9-CM 723.0-723.9,728.0-729.9, 781.0-781.9, 840.0-842.19.

Exclusions were any arm or hand diagnoses attributable to acute injury or trauma. Further, only a single case report for each individual was recorded for the study (see statistical methods).

The two study sample sources were comprehensively reviewed both manually and electronically to identify all individuals reported to both systems. To ensure that all potential matching cases were noted, the 1995 WCC reports were compared to adjacent years of the physician database, since it is possible that cases may not have been reported to both systems in the same year. The physician report figures include all 1995 cases plus any matching non-1995 cases that were listed as 1995 in the WCC data. To take into account the possibility of name mis-spellings and changes to maiden name, we used both computer and hand matching utilizing last name, first name, and employer name. Cases were matched across WRMSD categories since at times the description of disease was different between the systems. The specific type of WRMSD for categorizing cases was defined by the physician's diagnosis in the ODSS data if there was a discrepancy concerning the type of WRMSD between the two data sources. A match was assumed if there were slight discrepancies between descriptions of a case between the two data

sources. This is the more conservative approach, since it will reduce the estimate for un-captured cases (because a higher proportion of overlapping cases results in a lower estimate of un-captured cases).

Statistical Methods:

Maximum likelihood estimation was used to estimate the number of un-captured cases for each of the four diagnostic subgroups and for total WRMSD. These estimates will be biased for the low prevalence conditions, however this bias is negligible in estimating conditions of greater prevalence and overall totals. The summed maximum likelihood estimate is reported for the overall number of cases for all conditions; it is simply the sum of the maximum likelihood estimates for the four conditions. (Hook and Regal, 1993). Approximate confidence intervals were calculated by inversion of the likelihood ratio test (Regal and Hook, 1984). A confidence interval for the overall number of cases was calculated for the summed estimate by treating each condition as a subgroup in a loglinear model and inverting the likelihood ratio test (Hook and Regal, 1993). The loglinear model requires that there be no case overlap, i.e., that no person has more than one condition. In fact, 14/793 persons captured did indeed report more than one condition; we ignore this 1.75% error in our estimates of the total number of cases. Estimates for total WRMSD were calculated to take into account the different capture probabilities of the four diagnostic subgroups following Hook and Regal (1993).

Results

Capture- Recapture Estimates from Workers' Compensation and Surveillance

Table 1 shows WRMSD cases by diagnostic subgroup for the WCC and ODSS databases, including totals for cases reported to one system but not the other, as well as the number of case overlaps common to both systems. As expected, diagnoses are less precise for the WCC database, with a larger number of muscle "inflammation/pain" cases which had been categorized as upper extremity "repetitive strain injuries" based on the reported injury type and location. Among other diagnoses, carpal tunnel syndrome is the most prevalent condition, followed by tendonitis and HAVS.

There was very little overlap between the WCC and ODSS reporting systems. Overall, overlaps were seen in only 6.7% of reported WCC cases and 8.0% of ODSS cases for WRMSD. The maximum likelihood estimates for cases that were not captured by either system were 1,978 for carpal tunnel syndrome, 531 for tendonitis, 84 for hand-arm vibration Syndrome, and 10,692 for local inflammation/pain, with an estimated 13,285 un-captured (and hence unreported) WRMSD cases overall. Total CT 1995 annual WRMSD case estimates (the sum of those captured by either of the two systems plus the un-captured estimate) were 2,427 for carpal tunnel syndrome, 928 for tendonitis, 104 for HAVS, 11,227 for inflammation/pain, and 14,686 for all WRMSD cases. 95% confidence intervals are reported in Table 1. Based on these population estimates, only 5.4% of the 14,686 CT WRMSD cases were reported by workers' compensation insurance carriers in 1995. Among WRMSD case subgroups, a somewhat higher

percentage (11.6%) of carpal tunnel syndrome cases were reported.

Discussion

Study Limitations

Capture-recapture estimates, although useful in epidemiological applications, have well identified limitations. Capture-recapture studies assume that for the data sources, each case has similar "catchability." Accurate, comparable diagnosis of cases in source datasets is important to these studies. WRMSD case definitions are very similar, but not completely identical, between the WCC and ODSS datasets. Precise diagnostic information for cases is often lacking when assessing employers' workers' compensation reports, whereas diagnostic detail is greater in physician reporting systems. The percentage of overlapping cases relative to numbers reported to WCC and ODSS is the least for the less specific and typically less serious diagnostic category muscle "inflammation/pain." In the WCC data, this is the largest single diagnostic category, and hence WRMSD under-reporting estimates may be biased upward. There is greater case overlap (and less estimated under-reporting) for the diagnostic categories "tendonitis" and "carpal tunnel syndrome." This may be because better-defined conditions have higher reporting likelihood, or alternately could be an artifact of the type of physician specialties that typically report through the ODSS program. Medical specialists such as orthopedists may be somewhat under-represented in the ODSS database, and if severe WRMSD cases are more likely to be diagnosed by these providers, then a negative correlation between the two data sources could exist, leading to higher estimates of un-captured cases.

While lacking in diagnostic precision, our study diagnostic groupings, which are constructed on broad definitions of WRMSD, do achieve better comparability at the broader, aggregate level. Such broader level diagnostic constructs are thought to improve diagnostic validity for self-reported prevalence surveys (Colditz et al., 1986, Cox and Iachan, 1987). This strategy also increased matching precision, which is important for capture-recapture study validity. To further enhance precision, we employed both electronic and manual matching, including searching for matches by employer, first, and last name, and other demographic factors to reduce problems with misspellings and name changes. It is possible that a number of true matches remain undetected, a potential error that would also further bias our incidence estimates upward.

Capture-recapture analysis assumes equivalent time-space units for source data sets. This can be a problem since occupational diseases such as WRMSD tend to have gradual onset and are often reported well after onset of symptoms. We increased the likelihood of detecting case overlaps between the two sample sources by screening adjacent years of the physician's ODSS database for possible diagnostic matches. Further, capture-recapture analysis assumes a reference population closed to losses or entries during the study period. It is possible that some diagnosed WRMSD cases were reported as Workers' Compensation cases in jurisdictions other than Connecticut. We do not have available estimates to measure this potential bias, though we believe this is not likely to

represent a large study effect.

Capture-recapture analysis ideally assumes independence of the source samples. In this context, it is likely that WRMSD cases diagnosed by CT physicians are more likely to be reported to workers' compensation insurers, hence to some extent, the two source databases are not entirely independent. If present, such a positive correlation between source samples should, according to capture-recapture theory, result in an under-estimate of un-captured cases (Hook and Regal, 1995). This would bias study estimates for WRMSD lower, operating in the opposite direction to the potential biases previously discussed.

Overall, the capture-recapture analysis with our two-source data set is subject to several limitations, with potential biases of our estimates operating in different directions. Many of these biases potentially result in overestimates of unreported cases, and we therefore believe our estimates are best considered as an upper bound for the true population values. Despite the several limitations on the precision of our estimates, it is difficult to avoid the conclusion that there is considerable under-reporting of WRMSD cases in CT. Using the more conservative lower bound 95% confidence interval estimates, for example, we estimate the total unreported WRMSD cases at 10.5 times those reported to the CT Workers' Compensation Commission and 12.6 times the ODSS system. For carpal tunnel syndrome considered alone, these lower bound estimates are 3.6 times the number of Commission reported cases, and 5.3 times the number in ODSS reports.

Comparison With Other Population-Based WRMSD Prevalence Estimates

The current capture-recapture WRMSD estimates can be compared with other existing data on WRMSD in Connecticut. The 1996 Connecticut Upper-extremity Surveillance Project (CUSP) is a random digit dialing telephone interview survey of CT working-age individuals (Morse, et al, 1998, Warren et al., 2000). Study methodology has been previously described (Dillon, et al. 1999). This state level population-based prevalence survey was designed to replicate and extend the 1988 U.S. National Center for Health Statistics-Occupational Health Supplement survey (Massey et al., 1989, Tanaka, et al, 1995) with respect to upper extremity WRMSD.

CUSP survey data is self-reported, however it utilizes standard screening questions (Park et al., 1993) previously developed in National Institute for Occupational Safety & Health physical examination field studies designed to identify WRMSD cases with high probability (Baron et al., 1996). The national survey WRMSD case inclusion criteria were individuals with "prolonged" upper extremity symptoms (defined as pain or discomfort for seven or more consecutive days, or 20 or more total days within the previous year) who were medically attended for hand or upper extremity disorders (“medically-called” WRMSD cases). For present comparisons with the WCC and ODSS data sets, we extended this case definition to include only cases where both the medical provider and the worker reported that the condition was work related. Exclusion criteria

were any reported diagnosis not consistent with an occupational disorder, and cases attributable to sudden, acute injuries.

For WCC and ODSS comparisons, we used one-year WRMSD incidence estimates from the CUSP survey as the parameter best corresponding to the total number of potentially reportable 1995 WRMSD claims. Period and point prevalence estimates for WRMSD will largely overestimate total potentially reportable claims, as they include individuals with long term symptoms who are not reportable under CT statute.

In the CUSP data set, there were 25 medically-called WRMSD cases during the previous 12 months among the 3,200 individuals screened, giving a rate of 78 cases per 10,000 workers (95% CI 58-124). This produces an estimated annual incidence of 13,775 physician diagnosed WRMSD cases (95% confidence interval of 8,800-18,800) when extrapolated to the 1.52 million current workers in Connecticut (the eligible population for the survey). Of the 25 incident WRMSD cases, only 4 had been at time of interview reported to workers' compensation, suggesting that CT WRMSD are under reported by a factor of 7.25:1.

Capture-recapture analysis annual upper-extremity WRMSD estimates were just under 15,000 cases, compared to an estimate of just under 14,000 cases from the population-based CUSP survey, with similar confidence intervals (95% CI approximately 9,000 to 19,000 cases). The congruence between annual CT WRMSD estimates from studies using two different methodologies lends credence to our study estimates. However, the relatively wide confidence intervals argue that these estimates must be considered preliminary. Nevertheless, it appears likely that substantial numbers of WRMSD in Connecticut go unreported, as even the lower bound 95% confidence interval estimate for total WRMSD are several times the number of cases reported to the state's Workers' Compensation Commission.

Other Studies of Under-reporting

Studies limited to data from workers' compensation insurance claims cannot, by definition, estimate the magnitude of potentially reportable work injuries. Several other studies, however, provide information consistent with this study on the under-reporting of cases to workers' compensation. The studies of Liss et al. (1992) and Katz et al. (1998) estimate unreported carpal tunnel cases at 1.5 to 10 times those reported through workers' compensation systems. Further, Maizlisch et al. (1995) performed a county-level capture-recapture study of work related carpal tunnel cases in California. This study, although not of workers' compensation data, did compare work-related carpal tunnel cases reported through the California physician's 1st report of injury system to the state's Department of Labor to field surveillance data on carpal tunnel syndrome from the state's Sentinel Events Notification System for Occupational Risks. Work related carpal tunnel cases were found to be under-reported by a factor of 5.8. Fine et al. (1984) identified 4 to 10 times more WRMSD in two automobile manufacturing plants through review of personal medical records than through workers' compensation reports. In another industry based

study, Silverstein et al. (1997) found substantial under-reporting of WRMSD based on comparisons of health surveillance interview and physical examination compared to reporting on OSHA 200 Logs (which contain workers' compensation reports as a subset). Further, a non-randomized survey of unionized workers in Manitoba in 1992 reported by Yassi et al. (1996) found that only 47% of those who had been told by a doctor that they had a WRMSD had filed a workers' compensation claim. In a study of work-related spinal injuries, Chaffin (1979) found that only 10% of low back injuries at work were ultimately awarded workers' compensation. More recently, a statewide survey in Michigan (Rosenman et al., 2000) reported that only 25% of workers with known or suspected "repetitive trauma" disorders of the wrist, shoulder or back had filed for workers' compensation.

Under-reporting of occupational disorders may in fact represent a more general workplace phenomenon. Hensler, et al. (1991), for example, in a population-based telephone interview survey of work-related acute accidental injuries, found that only 43.5% of hospitalizations, 40.4% of outpatient visits, and 26.4% of lost work time costs were paid by workers' compensation insurers alone. Biddle et al. (1998) found for various workers' compensation diagnoses generally, that between 9 to 45% of workers with potential work-related injuries and illnesses actually filed WCC claims.

Conclusion

A number of previous studies with different methodologies indicate that substantial numbers of individuals with apparent work injuries never file workers' compensation claims. Our present study using capture-recapture methodology lends support to the hypothesis that large numbers of upper extremity work injuries are in fact un-reported either to workers' compensation insurers or to existing regulatory surveillance programs for occupational injuries and diseases. Further, our capture-recapture estimates of the total number of potentially reportable number of WRMSD in CT are generally congruent with estimates from recent population-based surveys in the state, increasing confidence in our overall estimates. It should be noted that our study only addresses under-reporting of the more severe lost-time WRMSD injury cases. The scope of WRMSD is in fact much larger than this, for example, Silverstein et al. (1998) estimate that lost time cases represented only approximately 36-42% of all WRMSD cases reported to workers' compensation insurers. Further, many workers choose not to seek medical care for their injuries, making job changes or other adaptations in preference to injury reporting.

Large-scale under-reporting of WRMSD has potentially important implications for the general economy, including substantial cost-shifting of WRMSD treatment to payment sources other than workers' compensation, such as group medical insurers and out-of-pocket expenses (Morse, et. al., 1998). It also has important implications for business, since reliance solely on workers' compensation insurance data reduces the employers' perceived economic advantages of injury and illness prevention. WRMSD under-reporting also significantly affects the scope of regulatory policy-making and resource allocation for programmatic prevention efforts.

In the future, it would be useful to develop refined versions of the capture-recapture injury study methodology to help provide more accurate periodic assessments of the levels and trends in WRMSD. For example it would be useful to know whether the recently observed trends in WRMSD incidence and prevalence reflect variations in injury reporting patterns, or true variation in injury rates or improvement in workplace conditions. The observed patterns in OSHA/BLS reported cases (dramatic increases followed by modest decreases over the last three years) could more accurately assessed as to their causes, and the actual effects of recent changes in workers' compensation insurance benefit levels, regulatory policies and employer practices could be more accurately delineated.

References

Ashbury FD, 1995. Occupational repetitive strain injuries and gender in Ontario, 1986 to 1991. Journal of Occupational and Environmental Medicine 37(4): 479-85.

Baron S, Hales T, Hurrell J, 1996. Evaluation of symptoms surveys for occupational musculoskeletal disorders. Am J Industrial Medicine 29(6):609-17.

Biddle J, Roberts K, Roseman D, and Welch E, 1998. What percentage of workers with work-related illnesses receive workers' compensation benefits. Journal of Occupational and Environmental Medicine 40(4):325-31.

Brogmus G, Sorock G, and Webster B, 1996. Recent trends in work-related cumulative trauma disorders of the upper extremities in the United States: An evaluation of possible reasons. Journal of Occupational and Environmental Medicine 38(4):401-11.

Chaffin DB, 1979. Manual materials handling, the cause of overexertion illness and injury in industry. Journal of Environmental Pathology and Toxicology 2:67-73.

Colditz GA, Martin P, Stampfer MJ, Willett WC, Sampson L, Rosner B, Hennekens CH, and Speizer FE. 1986. Validation of questionnaire information on risk factors and disease outcomes in a prospective cohort study of women. Am J Epidemiol 123:894-900.

Connecticut Department of Labor, ConnOSHA, 1981 to 1998. Occupational Injuries and Illnesses in Connecticut.

Cox BG and Iachan R, 1987. A comparison of household and provider reports of medical conditions. J Am Stat Assoc 82:1013-18.

Dillon CF. Morse TF, and Warren, N, 1999. Upper Extremity Repetitive Strain Injuries in Connecticut 1996, Extent and Costs: A Technical Report. NIOSH RO1 CCR112118-03.

Ekberg K, Bjorkqvist B, Malm P, Bjerre-Kiely B, Karlsson M and Axelson O, 1994. Case-control study of risk factors for disease in the neck and shoulder area. Occupational and Environmental Medicine 51(4):262-66.

El-Khorazaty M, Imreg PB, Koch GG, and Wells HB. 1977. Estimating the total number of events with data from multiple-record systems: a review of methodological strategies. Int Stat Review 45:129-57.

English, C J, Maclaren WM, Court-Brown C, Hughes SPF, Porter RW, Wallace WA, Graves RJ, Pethick AJ, and Soutar CA, 1995. Relations between upper limb soft tissue disorders and repetitive movements at work. American Journal of Industrial Medicine 27(1): 75-90.

Fine LJ, Silverstein BA, Armstrong TJ, and Anderson CA, 1984. An alternative way of detecting cumulative trauma disorders of the upper extremity in the workplace. Proceedings of the 1984 International Conference on Occupational Ergonomic Human Factors Association, Toronto, Ontario, International Conference on Occupational Ergonomics. p 425-429.

Fine LJ, Silverstein BA, Armstrong TJ, Anderson CA, Sugano DS, 1986. Detection of cumulative trauma disorders of upper extremities in the workplace. Journal of Occupational Medicine 28(8):674-78.

Frazier LM, Loomis DP, 1996. Usefulness of North Carolina workers' compensation data for surveillance of cumulative trauma disorders. Applied Occupational and Environmental Hygiene 11(9):1125-30.

Gerr F, Letz R, and Landrigan P, 1991. Upper-extremity musculoskeletal disorders of occupational origin. Annual Review of Public Health 12:543-66.

Hensler DR, Marquis MS, Abrahamse AF, Berry SH, Ebener PA, Lewis EG, Lind EA, MacCoun RJ, Manning WG, Rogowski JA, and Vaiana ME, 1991. Compensation for accidental injuries in the United States. Santa Monica, CA: RAND.

Hook EB, Regal RR, 1992. The value of capture-recapture methods even for apparent exhaustive surveys. American Journal of Epidemiology 135(9):1060-67.

Hook EB, Regal, RR, 1993. Effect of variation in probability of ascertainment by sources ("variable catchability") upon "capture-recapture" estimates of prevalence. American Journal of Epidemiology 137:1148-66.

Hook EB, Regal, RR, 1995. Capture-recapture methods in epidemiology: methods and limitations. Epidemiologic Reviews 17(2):243-64.

Katz JN, Lew RA, Bessette L, Punnett L, Fossel AH, Mooney N, and Keller RB, 1998. Prevalence and predictors of long-term work disability due to carpal tunnel syndrome. American Journal of Industrial Medicine 33:543-50.

Korrick SA, Rest KM, Davis LK, and Christiani DC, 1994. Use of state workers' compensation data for occupational carpal tunnel syndrome surveillance: A feasibility study in Massachusetts. American Journal of Industrial Medicine 25(6):837-50.

Kraut A, 1994. Estimates of the extent of morbidity and mortality due to occupational diseases in Canada. American Journal of Industrial Medicine 25(2):267-78.

Liss GM, Armstrong C, Kusiak RA, Gailitis MM, 1992. Use of provincial health insurance plan billing data to estimate carpal tunnel syndrome morbidity and surgery rates. American Journal of Industrial Medicine 22(3):395-409.

Maizlish N, Rudolf L, Dervin K, Sankaranarayan M, 1995. Surveillance and prevention of work-related carpal tunnel syndrome: an application of the sentinel events notification system for occupational risks. American Journal of Industrial Medicine 27:715-29.

Massey JT, Moore TF, Parsons VL, Tadros, W, 1989. Design and estimation for the National Health Interview Survey, 1985-1994. National Center for Health Statistics, Vital Health Stat 2 110:89-1384.

Miller RF, Lohman WH, Maldonado G, and Mandel JS, 1994. An epidemiologic study of carpal tunnel syndrome and hand-arm vibration syndrome in relation to vibration exposure. Journal of Hand Surgery 19A(1):99-105.

Morse TF, Dillon C, Warren N, Levenstein C, and Warren A, 1998. The economic and social consequences of work-related musculoskeletal disorders: The Connecticut upper-extremity surveillance project (CUSP). International Journal of Occupational and Environmental Medicine 4(4):209-16.

Oleinick A, Gluck JV, Guire KE, 1995. Establishment size and risk of occupational injury. American Journal of Industrial Medicine 28(1):1-21.

Park CH, Wagener DK, Winn DM, Pierce JP, 1993. Health conditions among the currently employed. Vital Health Stat 10 186:1-67.

Regal, RR and Hook, EB, 1984. Goodness-of-fit based confidence intervals for estimates of the size of a closed population. Statistics in Medicine 3:287-91.

Rosenmann KD, Gardiner JC, Wang J, Biddle J, Hogan A, Reilly MJ, Roberts K, Welch E. 2000. Why most workers with occupational repetitive trauma do not file for workers' compensation. Journal of Occupational and Environmental Medicine 42(1):25-34.

Rossignol M, 1994. Completeness of provincial workers' compensation files to identify fatal occupational injuries. Canadian Journal of Public Health 85(4):244-47.

Seber, GA, 1982. The estimation of animal abundance and related parameters. 2nd edition. London, Charles Griffin.

Silverstein BA, Stetson DS, Keyserling WM, Fine LJ, 1997. Work-related musculoskeletal disorders: comparison of data sources for surveillance. Am J Ind Med 31(5):600-8.

Silverstein BA, Welp, E, Nelson, N, Kalat, J, 1998. Claims incidence of work-related disorders of the upper extremities: Washington state, 1987 through 1995. American Journal of Public Health 88(12):1827-33.

Tanaka S, Wild DK, Seligman PJ, Halperin WE, Behrens VJ, Putz-Anderson V, 1995. Prevalence and work-relatedness of self-reported carpal tunnel syndrome among U.S..

workers: analysis of the Occupational Health Supplement Data of 1988 National Health Interview Survey. American Journal of Industrial Medicine 27(4):451-70.

Tanaka S, Seligman P, Halperin W, Thun M, Timbrook CL, Wasil JJ, 1988. Use of workers' compensation claims data for surveillance of cumulative trauma disorders. Journal of Occupational Medicine 30(6)488-92.

Warren N, Dillon CF, Morse T, Hall C, 2000. The Connecticut upper extremity disorder surveillance project: biomechanical, psychosocial, organizational risk factors for work related musculoskeletal injuries. Journal of Occupational Health Psychology 5(1):164-81.

Yassi A, Sprout J, Tate R, 1996. Upper limb repetitive strain injuries in Manitoba", American Journal of Industrial Medicine 30:461-72.

Table I. Capture-Recapture Analysis of Connecticut Work-Related Musculoskeletal Disorders, 1995.

Injury Group	Unique ODSS Cases	Unique WCC Cases	Overlap Cases In Both	Estimated Un-Captured Cases	95% CI	Estimated Total CT Cases	95%CI
Carpal Tunnel	168	259	22	1,978	999-2,298	2,427	1,448-2,747
Tendonitis	329	42	26	531	0-341	928	397-738
HAVS	12	7	1	84	41-97	104	61-117
Muscle Pain, Inflammation	99	432	4	10,692	7,292-14,316	11,227	7,827-14,851
Total	608	740	53	13,285	8,332-17,052	14,686	9,733-18,453

WCC=Workers' Compensation Commission Reported Injury Cases (does not include overlapped cases); ODSS=CT physician's Occupational Disease & Injury Reporting System (does not include overlapped cases); CI=confidence interval; HAVS= hand-arm vibration syndrome.