

UC Berkeley

UC Berkeley Previously Published Works

Title

Associations between workplace factors and carpal tunnel syndrome: A multi-site cross sectional study.

Permalink

<https://escholarship.org/uc/item/1636x74s>

Journal

American journal of industrial medicine, 58(5)

ISSN

0271-3586

Authors

Fan, Z Joyce
Harris-Adamson, Carisa
Gerr, Fred
[et al.](#)

Publication Date

2015-05-01

DOI

10.1002/ajim.22443

Peer reviewed



Published in final edited form as:

Am J Ind Med. 2015 May ; 58(5): 509–518. doi:10.1002/ajim.22443.

Associations between Workplace Factors and Carpal Tunnel Syndrome: A Multi-site Cross Sectional Study

Z. Joyce Fan, PhD^a, Carisa Harris-Adamson, PhD, PT^{b,c}, Ellen A Eisen, ScD^b, Kurt T. Hegmann, MD^d, Barbara Silverstein, PhD^e, Ann Marie Dale, PhD^f, Bradley Evanoff, MD^f, Matthew S. Thiese, PhD^d, Jay Kapellusch, PhD^g, Arun Garg, PhD^g, Susan Burt, ScD^h, Fred Gerr, MDⁱ, Linda Merlino, MSⁱ, David Rempel, MD^j

^aWashington Traffic Safety Commission, Olympia, WA, USA;

^bDepartment of Environmental Health Sciences, University of California Berkeley, Berkeley, CA, USA;

^cDepartment of Physical Therapy, Samuel Merritt University, Oakland, CA, USA;

^dRocky Mountain Center for Occupational and Environmental Health (RMCOEH), University of Utah, Salt Lake City, UT, USA;

^eSafety and Health Assessment and Research for Prevention (SHARP) Program, Washington State Department of Labor and Industries, Olympia, WA, USA,

^fDivision of General Medical Science, Washington University School of Medicine, Saint Louis, MO, USA;

^gCenter for Ergonomics, University of Wisconsin-Milwaukee, Milwaukee, WI, USA;

^hNational Institute for Occupational Safety and Health (NIOSH), Cincinnati, OH, USA;

ⁱUniversity of Iowa, Department of Occupational and Environmental Health, College of Public Health, Iowa City, IA, USA;

^jDivision of Occupational and Environmental Medicine, University of California at San Francisco, San Francisco, CA, USA;

Abstract

Background: Few large epidemiologic studies have used rigorous case criteria, individual-level physical exposure measurements, and appropriate control for confounders to examine associations between biomechanical factors and risk of carpal tunnel syndrome (CTS).

Methods: Pooling data from six independent research studies, we assessed associations between the prevalence of CTS and estimates of force, repetition, posture and composite measures of biomechanical factors, while adjusting for confounders using multivariable logistic regression.

Results: Personal factors of older age, female gender, obese, and medical conditions (diabetes mellitus, rheumatoid arthritis, thyroid disease, pregnancy) and workplace measures of forceful hand activity (analyst or worker related Borg CR-10 and the Threshold Limit Value for Hand Activity Level) were related to CTS prevalence.

Conclusions: In this cross-sectional study of production and service workers, CTS prevalence was associated with personal and work related factors.

Keywords

musculoskeletal disorders; physical work load; workers; individual-level assessment; confounders

Introduction

Carpal tunnel syndrome (CTS) is characterized by numbness, tingling, burning or pain in the thumb, index and long fingers of the hand and slowing of median nerve conduction at the wrist due to entrapment of the median nerve in the carpal tunnel [Moore, 1992; Stevens, 1997]. CTS cases related to occupational exposures result in a substantial burden of worker's compensation claims, lost work time and productivity, and disability [Foley, et al., 2007; Manktelow, et al., 2004; Silverstein and Adams, 2007]. Due to differences in populations studied, risk factors examined, study design, and CTS case definition, there are wide ranges in the reported prevalence and incidence of electrophysiologically-confirmed CTS [ACOEM, 2011; Descatha, et al., 2011; Rempel, et al., 1998]. Prevalence of CTS in working populations ranges from 1.7% to 21% [Armstrong, et al., 2008; Dale, et al., 2013; Gorsche, et al., 1999; Maghsoudipour, et al., 2008; Roquelaure, et al., 2001] and are generally higher than the rates of 1% to 4.9% observed among members of the general population [Atroshi, et al., 1999; de Krom, et al., 1992; Stevens, et al., 1988; Tanaka, et al., 1994]. Similarly, the incidence of CTS in workers (0.23 to 11 per 100 person-years) [Gorsche, et al., 1999; Roquelaure, et al., 2008; Silverstein and Adams, 2007; Bonfiglioli et al., 2013] is higher than that in the general population (0.18 to 0.28 per 100 person-years) [Bongers, et al., 2007; Mondelli, et al., 2002].

Previous studies have reported risk factors for CTS that include personal, psychosocial, and job physical exposures. Personal factors include older age [Atroshi, et al., 1999; Stevens, et al., 1988], female gender [Geoghegan, et al., 2004; Shiri, et al., 2007; Silverstein and Adams, 2007; Solomon, et al., 1999; Tanaka, et al., 1994], obesity [Boz, et al., 2004; Geoghegan, et al., 2004], diabetes mellitus [Geoghegan, et al., 2004], thyroid disease [Roquer and Cano, 1993; Tanaka, et al., 1994], inflammatory arthritis [Geoghegan, et al., 2004; Solomon, et al., 1999] and pregnancy [Zyluk, 2013]. A few studies have assessed the role of occupational psychosocial factors, reporting associations between incident CTS and high job demand, high job strain, and psychosocial distress [Harris-Adamson, et al., 2013; Roquelaure, et al., 2001; Silverstein, et al., 2010]. Work-related CTS has also been associated with high hand force (forceful pinch or power grip) often in combination with high repetition, and hand-arm vibration [Shiri, et al., 2009; Silverstein, et al., 2009; Silverstein, et al., 2010; Werner, 2006; Bonfiglioli et al. 2013; Burt et al. 2013].

Some studies of CTS risk factors have been criticized for use of imprecise or unreliable exposure measures (e.g. job title), small samples sizes, retrospective methods, inadequate control of confounders, and samples that were not representative of workers and industries [Frost, et al., 1998; Gell, et al., 2005; Hegmann and Oostema, 2008; Roquelaure, et al., 2008]. To date, few large epidemiologic studies used rigorous case criteria, individual-level

physical exposure measurements, and appropriate control of confounding by personal and psychosocial factors when exploring associations between biomechanical factors and risk of CTS [Violante, et al., 2007; Bonfiglioli et al. 2013].

The current manuscript presents the results from analyses of baseline pooled data collected by six prospective studies of upper extremity disorders among US production and service workers. We assessed the associations between prevalence of CTS at study inception and estimates of force, repetition, posture and composite measures of biomechanical factors, while adjusting for historical and important confounding factors. Findings of the prospective analyses of the incident CTS cases are presented in a other papers.

Methods

Study design and participants

As part of a consortium of [National Institute of Occupational Safety and Health \(NIOSH\)](#)-funded studies of risk factors for upper extremity MSDs in industry, baseline data were pooled from six independent prospective epidemiological studies conducted at 50 US companies with workers employed in production, agriculture, construction and service sectors. Each of the six datasets included a uniform CTS case definition for dominant-hand, personal and psychosocial factors, and individual-level measurements of job physical exposure. Details on the study designs, the process of pooling data, and baseline CTS prevalence are provided elsewhere [Dale, et al., 2013; Harris-Adamson, et al., 2013]. Briefly, for all six studies, similar questionnaires were administered to participants at study enrollment to collect information on work history, demographics, medical history, musculoskeletal symptoms, and psychosocial work environment. In addition, electrodiagnostic studies (EDS) of the median and ulnar nerves at the wrist were collected at baseline by clinicians blinded to exposure status [Harris-Adamson, et al., 2013].

Of the 4,321 participants pooled from the six studies, we excluded 58 persons who met electrophysiological criteria for polyneuropathy [Dale, et al., 2013] and 1,282 subjects who had incomplete demographic or exposure data. Therefore, this cross-sectional analysis included 2,981 workers.

Study outcome

The study outcome was CTS in the dominant hand at the time of enrollment. The CTS case definition required (i) dominant hand symptoms that met study criteria (described below) and (ii) EDS results consistent with median nerve mono-neuropathy at the wrist [Gerr and Letz, 1998; Rempel, et al., 1998]. The symptom criteria were numbness, tingling, burning, and/or pain in the thumb, index finger, or long finger. Median nerve mono-neuropathy was defined as temperature adjusted: (1) peak median sensory latency >3.7ms or onset median sensory latency >3.2ms at 14cm, (2) motor latency >4.5ms, (3) transcarpal sensory difference of > 0.8ms (the difference in sensory latencies between the median and ulnar nerves across the wrist), and/or (4) an unobtainable latency value consistent with an abnormal NCS (Dale et al., 2013). Workers with prior CTS surgery were also included as baseline cases (N=32).

Physical exposure factors

Details on the collection of workplace physical exposure measures from each site as well as methods used for pooling physical exposure data are reported elsewhere [Kapellusch, et al., 2013]. Briefly, all sites ensured that measures of hand force, repetition, posture and vibration were collected at the task level [Chiang, et al., 1993; Fung, et al., 2007; Garg, et al., 2012; Maghsoudipour, et al., 2008; Silverstein, et al., 1987]. Specifically, hand force ratings (Borg CR-10 scale, Borg 1982) were assessed by both workers and analysts. Duty cycle was quantified for all hand exertions and as well as for only forceful hand exertions from video tape analysis. Forceful hand exertion was defined as greater than 10N pinch force or 45N of grip force. Repetition was assessed by trained analysts using the 10-point American Conference of Governmental Industrial Hygienists (ACGIH) Hand Activity Level (HAL) scale. The analyst TLV for HAL was calculated using the analyst's peak force rating and analyst HAL rating. Posture was quantified from videotapes of participants doing their job tasks as the percent time spent in >30° wrist extension and the percent time spent in >30° wrist flexion. Hand/arm vibration (yes/no) was recorded by task if there was visible hand/arm vibration or use of vibratory hand-tools; this information was collected by 4 of the 5 sites.

Workers typically performed one to two tasks but could have up to eight tasks. For workers whose job involved more than one task, task level exposures were combined to produce a job level exposure. Specifically, for each worker, exposure was assessed at the job level by combining task level data using three summary measures: 1) peak exposure (e.g. highest force, highest frequency of exertion, worst posture), 2) typical exposure (i.e. exposure from the task performed most of the time) and 3) time-weighted average exposure across all tasks. There were high correlations between job level exposure measures (e.g. peak, typical, and time-weighted average), with Spearman correlation coefficient $\rho=0.85$ to 0.97 . Time-weighted average measures, therefore, were used for this analysis.

Personal and Psychosocial Factors

Information about age, gender, body mass index (BMI), race/ethnicity, education, smoking status, hand dominance, and co-morbid medical conditions such as rheumatoid arthritis, diabetes mellitus, thyroid disease, and pregnancy status was collected by questionnaire from all study participants. The total number of hours spent per week in recreational hand intensive and aerobic activities and the self-reported years worked at the current employer at enrollment were also collected. The occupational psychosocial factors assessed were co-worker or supervisor support, job demand, decision latitude, physical or mental exhaustion after work, and job satisfaction [Bigos, et al., 1991; Karasek, et al., 1998]. Of these psychosocial factors, data on co-worker or supervisor support were available from three sites and the other psychosocial variables were available from four research sites. Therefore, the sample sizes for these analyses are less than other analyses.

Statistical analysis

Multivariable logistic regression models were used to estimate associations between each of the 11 physical exposure variables and prevalent CTS while adjusting for age, gender, obesity, research site and other covariates. For each model, the physical exposure variables

(measures of force, repetition, duty cycle and posture) were converted to categorical values using cut points by tertiles based on the distribution in the pooled study population. TLV for HAL scores were categorized into three levels by the Action Limit (0.56) and Threshold Limit Value (TLV) (0.78) [Garg, et al., 2012].

Potential confounding by personal and psychosocial factors was evaluated empirically. Specifically, those covariates associated with the outcome ($p < 0.20$), that were not thought to be on the pathway from exposure to response, and had less than 10% missing data were initially included in each multivariable model. Covariates that changed the effect estimate of the primary exposure by more than 10% were retained in the final models.

All analyses were conducted using SAS (v9.3) statistical software (SAS, 2010).

Results

Of the 2,981 participants, 9.6% (N=287) met the criteria for CTS at baseline. Of these prevalent CTS cases, 32 (11.1%) had been previously diagnosed by a physician as having CTS (data not shown). Compared to the non-cases, CTS cases were older (>35 years-old), more likely to be female, obese, had other medical conditions (diabetes mellitus, rheumatoid arthritis, thyroid disease, and pregnancy), reported previous distal upper extremity disorders, and were past smokers (Table 1). There were no statistically significant differences between the CTS cases and non-cases on race/ethnicity, education, and general health status (Table 1).

CTS prevalence was increased among workers who reported spending more than 3 hours/week on recreational hand intensive and aerobic activities than those who spent less than 3 hours/week on these activities after adjusting for age, gender, obesity and research sites (Table 2). There was a significant association between being moderately to severely physically exhausted after work and CTS prevalence. Workers who were dissatisfied with their jobs had higher prevalence of CTS than those who were very satisfied, OR 1.56 (95% CI 1.09–2.24). Job demand, decision latitude, supervisor or co-worker support, mentally exhausted after work, job tenure, work shift, and job training were not significantly related to CTS prevalence.

Six job physical exposure measures were significantly associated with CTS prevalence after adjusting for age, gender, obesity, medical conditions and research site: percent time in forceful hand exertions (duty cycle), worker rated hand exertion (Borg CR-10), analyst rated hand exertion (Borg CR-10), forceful repetition rate, analyst rated TLV for HAL, and working with vibrating tools (Table 3). In contrast, total percent time in all hand exertion (duty cycle), total hand repetition rate, analyst's HAL rating (repetition), wrist extension 30° , and wrist flexion 30° were not significantly related to CTS prevalence.

Discussion

Jobs requiring high hand forces were associated with prevalent cases of CTS in this cross-sectional, multisite study. Overall, forceful hand activities as assessed by various measures, e.g., duty cycle, worker or analyst ratings, and repetition rate for forceful exertions, was

observed to be consistently and strongly associated with CTS after adjusting for covariates. On the other hand, total hand repetition rate and wrist posture were not. The composite index, that combines force and repetition, the ACGIH TLV© for HAL, was associated with CTS. Being older, female, obese, having another medical condition (diabetes mellitus, rheumatoid arthritis, thyroid disease, or pregnancy), having a previous upper extremity disorder, and doing recreational activities were also associated with an increased prevalence of CTS.

The observed association between higher hand force measures and CTS prevalence is consistent with previous studies. Forceful gripping greater than 1kg was associated with CTS in both a case-control [Roquelaure, et al., 1997] and a cross sectional study [Maghsoudipour, et al., 2008] and sustained forceful movement of the wrist was a risk factor for CTS in a case-control study [Fung, et al., 2007]. Peak hand force was found to predict risk of CTS in two prospective studies [Werner, et al., 2005; Bonfiglioli, et al., 2013].

Measures of hand repetition have been associated with CTS in some prior studies [Bonfiglioli, et al., 2006; Chiang, et al., 1990; Maghsoudipour, et al., 2008; Roquelaure, et al., 2001; Silverstein, et al., 1986; Bonfiglioli et al., 2013] but not others [McCormack, et al., 1990; Moore and Garg, 1994; Nathan, et al., 2005]. We found no statistically significant association between CTS and measures of total hand repetition based on video analysis of tasks or based on analyst estimates of repetition using the HAL scale. In contrast, CTS was related to hand repetition rate if repetition rate only considered forceful hand exertions (e.g., 10N pinch force or 45N grip force). The video analysis for total hand repetition rate counted all wrist and finger motions whether an external force was applied or not. In most prior studies it has not been specified what the minimal hand exertion level should be to be counted as a repetition. Since the composite index of analyst's TLV for HAL ratings were the combination of the HAL repetition measure and force rating by analysts, the significant associations between TLV for HAL and the prevalence of CTS appear to be primarily due to the contribution from the force rating. Thus, these results and those of others [McCormack, et al., 1990; Moore and Garg, 1994; Nathan, et al., 2005] suggest that repetition per se may not be as potent a risk factor as force.

There was a significant association between use of vibrating tools and CTS prevalence after adjusting for age, gender, obesity, medical conditions, and research sites. This finding is compatible with previous studies of quarry/rock drillers, stonemasons, and forestry workers exposed to hand-arm vibration [Bovenzi, 1994; Farkkila, et al., 1988; Barcenilla et al. 2012].

Many previous epidemiologic studies of CTS that have assessed hand-wrist posture have failed to observe significant associations between posture and CTS [Moore and Garg, 1994; Nordstrom, et al., 1998; Roquelaure, et al., 1997; Silverstein, et al., 1986; Silverstein, et al., 1987]. However, some cross-sectional or case-control studies have identified posture such as bending or twisting of the hands or wrists over 30 degrees [Maghsoudipour, et al., 2008] or frequent flexion or extension [de Krom, et al., 1990; Fung, et al., 2007] as risk factors. In our study, neither video assessed time in wrist extension 30° nor wrist flexion 30° was significantly associated with CTS prevalence. However, the average percent time that subjects were in wrist flexion was small (< 3%).

A number of personal factors have been reported as risk factors for CTS. Our findings on age >50 and obesity add to the large body of epidemiological evidence demonstrating associations between CTS and age [Atroshi, et al., 1999; Stevens, et al., 1988; Harris et al., 2013] and BMI [Boz, et al., 2004; Geoghegan, et al., 2004; Nordstrom, et al., 1997]. Although the association between CTS and female gender has been observed in previous studies, [Shiri, et al., 2007; Solomon, et al., 1999; Tanaka, et al., 1994] some authors have reported that the strength of the association was attenuated after adjusting for occupational hand activities [Franklin, et al., 1991; Nordstrom, et al., 1997]. In our analysis, however, the effect of female gender persisted even after adjusting for other important personal and physical exposure factors (data not shown). Some medical conditions have been associated with CTS in previous cross-sectional studies, e.g., diabetes mellitus [Geoghegan, et al., 2004], thyroid disease [Roquer and Cano, 1993; Tanaka, et al., 1994], inflammatory arthritis [Geoghegan, et al., 2004; Solomon, et al., 1999] and pregnancy [Zyluk, 2013].

Relatively few studies have assessed psychosocial factors as a risk for CTS and no consistent associations have been identified [Leclerc, et al., 2001; Nordstrom, et al., 1997; Werner, et al., 1998]. High job strain and low supervisor and co-worker support were observed to increase the risk of incident CTS in the prospective component of our study [Harris-Adamson, et al., 2013] but that association was not observed in this cross-sectional component. In the prospective analyses of our pooled data set job satisfaction was not associated with CTS [Harris-Adamson, et al., 2013] but in this cross-sectional analysis it was. This seemingly contradictory finding suggests that job satisfaction is not be a predictor of CTS but instead is related to the impact of CTS symptoms on ability to perform the job or the response of the employer to the report of symptoms. Job satisfaction was only collected by four research sites.

Some of the personal and psychosocial variables were not included in the final models for workplace physical factors because they either had missing data >10% (recreational hand intensive or aerobic activities) or were considered to be intermediate variables on the causal pathway between physical exposure and CTS (i.e., previous distal upper extremity disorders and self-reported physically exhaustion after work).

The strength of the current analyses include a large sample size, multi-site collection of data, rigorous CTS case criteria, individual-level physical exposure measures, and control for many confounders of associations between biomechanical risk factors and the CTS prevalence. Pooling data from multiple research sites allowed for wide job exposure variances among a diverse group of industries and occupations. Therefore, the findings are generalizable to a broad range of workplaces.

A few important limitations of these analyses are worth noting. First, these are cross-sectional analyses of baseline variables only. Even though the results provide a better understanding of potential risk factors, we were unable to evaluate the temporal relationships between exposures and outcome. It is possible that some persons who experienced CTS moved from higher exposure to lower exposure (i.e., selective survival), thereby attenuating the strength of some associations. Second, methodological differences between sites in physical exposure data collection and/or analysis may lead to some non-differential

misclassification of exposure category in the pooled analysis. However, this type of misclassification is likely to bias the findings toward the null. Third, while the intent of pooling data from multiple research sites was to increase the statistical power, there were practical problems resulting from variations in the prevalence of CTS and some missing data from the individual research sites. The psychosocial data was not collected by all sites and one site did not collect information on vibrating hand tools. So for these variables the sample sizes were smaller. As a result, the multivariable regression models assessing the role of these variables were conducted for a subset of pooled data.

Conclusion

In this large multi-site cross-sectional study, we found that jobs requiring high hand force were associated with an increased CTS prevalence after adjusting for important confounders. Overall, hand force was observed to be consistently and strongly associated with the prevalence of CTS, while repetition per se and wrist posture were not.

Acknowledgements

This study was funded, in part, by a grant from the National Institute for Occupational Safety and Health (NIOSH/CDC) R01-OH009712. Its contents are solely the responsibility of the authors and do not necessarily represent the official view of NIOSH.

References

- ACGIH. 2000. Threshold limit values for chemical substances and physical agents and biological exposure indices.
- ACOEM. 2011. American College of Occupational and Environmental Medicine's Occupational Medicine Practice Guidelines, 3rd Edition, Chapter 13: Hand, Wrist, and Forearm. In: Hegmann K, Hughes MA, Biggs JJ (Eds) editor. American College of Occupational and Environmental Medicine's Occupational Medicine Practice Guidelines, 3rd Edition, Elk Grove Village, IL: ACOEM.
- Armstrong TN, Dale AM, Al-Lozi MT, Franzblau A, Evanoff BA. 2008. Median and ulnar nerve conduction studies at the wrist: criterion validity of the NC-stat automated device. *J Occup Environ Med* 50: 758–764. [PubMed: 18617831]
- Atroshi I, Gummesson C, Johnsson R, Ornstein E, Ranstam J, Rosen I. 1999. Prevalence of carpal tunnel syndrome in a general population. *JAMA* 282: 153–158. [PubMed: 10411196]
- Bigos SJ, Battie MC, Spengler DM, Fisher LD, Fordyce WE, Hansson TH, Nachemson AL, Wortley MD. 1991. A prospective study of work perceptions and psychosocial factors affecting the report of back injury. *Spine (Phila Pa 1976)* 16: 1–6. [PubMed: 1825891]
- Barcenilla A, March LM, Chen JS, Sambrook PN. Carpal tunnel syndrome and its relationship to occupation: a meta-analysis. *Rheumatology* 2012; 51(2):250–61. [PubMed: 21586523]
- Bonfiglioli R, Mattioli S, Spagnolo MR, Violante FS. 2006. Course of symptoms and median nerve conduction values in workers performing repetitive jobs at risk for carpal tunnel syndrome. *Occup Med (Lond)* 56: 115–121. [PubMed: 16371398]
- Bonfiglioli R, Botter A, Calabrese M, Mussoni P, et al. 2012. Surface electromyography features in manual workers affected by carpal tunnel syndrome. *Muscle and Nerve* 45(6):873–882. [PubMed: 22581542]
- Bonfiglioli R, Mattioli S, Armstrong T, et al. 2013. Validation of the ACGIH TLV for hand activity in the OCTOPUS cohort: a two-year longitudinal study of carpal tunnel syndrome. *Scand J Work Environ Health*. 39(2):155–63. [PubMed: 22752342]

- Bongers FJ, Schellevis FG, van den Bosch WJ, van der Zee J. 2007. Carpal tunnel syndrome in general practice (1987 and 2001): incidence and the role of occupational and non-occupational factors. *Br J Gen Pract* 57: 36–39. [PubMed: 17244422]
- Bovenzi M. 1994. Hand-arm vibration syndrome and dose-response relation for vibration induced white finger among quarry drillers and stoneworkers. Italian Study Group on Physical Hazards in the Stone Industry. *Occup Environ Med* 51: 603–611. [PubMed: 7951792]
- Boz C, Ozmenoglu M, Altunayoglu V, Velioglu S, Alioglu Z. 2004. Individual risk factors for carpal tunnel syndrome: an evaluation of body mass index, wrist index and hand anthropometric measurements. *Clin Neurol Neurosurg* 106: 294–299. [PubMed: 15297003]
- Burt S, Deddens JA, Crombie K, Jin K, Wurzelbacher S, Ramsey J. 2013. A prospective study of carpal tunnel syndrome: workplace and individual risk factors. *Occup Environ Med* 70(8):568–74. [PubMed: 23788614]
- Chiang HC, Chen SS, Yu HS, Ko YC. 1990. The occurrence of carpal tunnel syndrome in frozen food factory employees. *Gaoxiong Yi Xue Ke Xue Za Zhi* 6: 73–80. [PubMed: 2352318]
- Chiang HC, Ko YC, Chen SS, Yu HS, Wu TN, Chang PY. 1993. Prevalence of shoulder and upper-limb disorders among workers in the fish-processing industry. *Scand J Work Environ Health* 19: 126–131.
- Dale AM, Harris-Adamson C, Rempel D, Gerr F, Hegmann K, Silverstein B, Burt S, Garg A, Kapellusch J, Merlino L, Thiese MS, Eisen EA, Evanoff B. 2013. Prevalence and incidence of carpal tunnel syndrome in US working populations: pooled analysis of six prospective studies. *Scand J Work Environ Health* 39: 495–505. [PubMed: 23423472]
- de Krom MC, Kester AD, Knipschild PG, Spaans F. 1990. Risk factors for carpal tunnel syndrome. *Am J Epidemiol* 132: 1102–1110. [PubMed: 2260542]
- de Krom MC, Knipschild PG, Kester AD, Thijs CT, Boekkooi PF, Spaans F. 1992. Carpal tunnel syndrome: prevalence in the general population. *J Clin Epidemiol* 45: 373–376. [PubMed: 1569433]
- Descatha A, Dale AM, Franzblau A, Coomes J, Evanoff B. 2011. Comparison of research case definitions for carpal tunnel syndrome. *Scand J Work Environ Health* 37: 298–306. [PubMed: 21301789]
- Farkkila M, Pyykko I, Jantti V, Aatola S, Starck J, Korhonen O. 1988. Forestry workers exposed to vibration: a neurological study. *Br J Ind Med* 45: 188–192. [PubMed: 2831932]
- Foley M, Silverstein B, Polissar N. 2007. The economic burden of carpal tunnel syndrome: long-term earnings of CTS claimants in Washington State. *Am J Ind Med* 50: 155–172. [PubMed: 17216630]
- Franklin GM, Haug J, Heyer N, Checkoway H, Peck N. 1991. Occupational carpal tunnel syndrome in Washington State, 1984–1988. *Am J Public Health* 81: 741–746. [PubMed: 1827570]
- Frost P, Andersen JH, Nielsen VK. 1998. Occurrence of carpal tunnel syndrome among slaughterhouse workers. *Scand J Work Environ Health* 24: 285–292. [PubMed: 9754860]
- Fung BK, Chan KY, Lam LY, Cheung SY, Choy NK, Chu KW, Chung LY, Liu WW, Tai KC, Yung SY, Yip SL. 2007. Study of wrist posture, loading and repetitive motion as risk factors for developing carpal tunnel syndrome. *Hand Surg* 12: 13–18. [PubMed: 17613179]
- Garg A, Kapellusch J, Hegmann K, Wertsch J, Merryweather A, Deckow-Schaefer G, Malloy EJ. 2012. The Strain Index (SI) and Threshold Limit Value (TLV) for Hand Activity Level (HAL): risk of carpal tunnel syndrome (CTS) in a prospective cohort. *Ergonomics* 55: 396–414. [PubMed: 22397385]
- Gell N, Werner RA, Franzblau A, Ulin SS, Armstrong TJ. 2005. A longitudinal study of industrial and clerical workers: incidence of carpal tunnel syndrome and assessment of risk factors. *J Occup Rehabil* 15: 47–55. [PubMed: 15794496]
- Geoghegan JM, Clark DI, Bainbridge LC, Smith C, Hubbard R. 2004. Risk factors in carpal tunnel syndrome. *J Hand Surg Br* 29: 315–320. [PubMed: 15234492]
- Gerr F, Letz R. 1998. The sensitivity and specificity of tests for carpal tunnel syndrome vary with the comparison subjects. *J Hand Surg Br* 23: 151–155. [PubMed: 9607648]
- Gorsche RG, Wiley JP, Renger RF, Brant RF, Gemer TY, Sasyniuk TM. 1999. Prevalence and incidence of carpal tunnel syndrome in a meat packing plant. *Occup Environ Med* 56: 417–422. [PubMed: 10474539]

- Harris-Adamson C, Eisen EA, Dale AM, Evanoff B, Hegmann KT, Thiese MS, Kapellusch JM, Garg A, Burt S, Bao S, Silverstein B, Gerr F, Merlino L, Rempel D. 2013. Personal and workplace psychosocial risk factors for carpal tunnel syndrome: a pooled study cohort. *Occup Environ Med* 70: 529–537. [PubMed: 23645610]
- Hegmann K, Oostema S. 2008. Causal associations and determination of work-relatedness. In: Melhorn JM aWEA editor. *Guides to the evaluation of Disease and Injury Causation* Chicago, IL AMA.
- Kapellusch JM, Garg A, Bao SS, Silverstein BA, Burt SE, Dale AM, Evanoff BA, Gerr FE, Harris-Adamson C, Hegmann KT, Merlino LA, Rempel DM. 2013. Pooling job physical exposure data from multiple independent studies in a consortium study of carpal tunnel syndrome. *Ergonomics* 56: 1021–1037. [PubMed: 23697792]
- Karasek R, Brisson C, Kawakami N, Houtman I, Bongers P, Amick B. 1998. The Job Content Questionnaire (JCQ): an instrument for internationally comparative assessments of psychosocial job characteristics. *J Occup Health Psychol* 3: 322–355. [PubMed: 9805280]
- Leclerc A, Landre MF, Chastang JF, Niedhammer I, Roquelaure Y. 2001. Upper-limb disorders in repetitive work. *Scand J Work Environ Health* 27: 268–278. [PubMed: 11560341]
- Maghsoudipour M, Moghimi S, Dehghaan F, Rahimpanah A. 2008. Association of occupational and non-occupational risk factors with the prevalence of work related carpal tunnel syndrome. *J Occup Rehabil* 18: 152–156. [PubMed: 18418702]
- Manktelow RT, Binhammer P, Tomat LR, Bril V, Szalai JP. 2004. Carpal tunnel syndrome: cross-sectional and outcome study in Ontario workers. *J Hand Surg Am* 29: 307–317. [PubMed: 15043907]
- McCormack RR Jr., Inman RD, Wells A, Berntsen C, Imbus HR. 1990. Prevalence of tendinitis and related disorders of the upper extremity in a manufacturing workforce. *J Rheumatol* 17: 958–964. [PubMed: 2213764]
- Mondelli M, Giannini F, Giacchi M. 2002. Carpal tunnel syndrome incidence in a general population. *Neurology* 58: 289–294. [PubMed: 11805259]
- Moore JS. 1992. Carpal tunnel syndrome. *Occup Med* 7: 741–763. [PubMed: 1411857]
- Moore JS, Garg A. 1994. Upper extremity disorders in a pork processing plant: relationships between job risk factors and morbidity. *Am Ind Hyg Assoc J* 55: 703–715. [PubMed: 7942507]
- Nathan PA, Istvan JA, Meadows KD. 2005. A longitudinal study of predictors of research-defined carpal tunnel syndrome in industrial workers: findings at 17 years. *J Hand Surg Br* 30: 593–598. [PubMed: 16129527]
- Nordstrom DL, Vierkant RA, DeStefano F, Layde PM. 1997. Risk factors for carpal tunnel syndrome in a general population. *Occup Environ Med* 54: 734–740. [PubMed: 9404321]
- Nordstrom DL, Vierkant RA, Layde PM, Smith MJ. 1998. Comparison of self-reported and expert-observed physical activities at work in a general population. *Am J Ind Med* 34: 29–35. [PubMed: 9617385]
- Rempel D, Evanoff B, Amadio P, de Krom M, Franklin G, Franzblau A, Gray R, Gerr F, Hagberg M, Hales T, Katz J, Pransky G. 1998. Consensus criteria for the classification of carpal tunnel syndrome in epidemiologic studies. *Am J Public Health* 88: 1447–1451. [PubMed: 9772842]
- Roquelaure Y, Mechali S, Dano C, Fanello S, Benetti F, Bureau D, Mariel J, Martin YH, Derriennic F, Penneau-Fontbonne D. 1997. Occupational and personal risk factors for carpal tunnel syndrome in industrial workers. *Scand J Work Environ Health* 23: 364–369. [PubMed: 9403467]
- Roquelaure Y, Mariel J, Dano C, Fanello S, Penneau-Fontbonne D. 2001. Prevalence, incidence and risk factors of carpal tunnel syndrome in a large footwear factory. *Int J Occup Med Environ Health* 14: 357–367. [PubMed: 11885919]
- Roquelaure Y, Ha C, Nicolas G, Pelier-Cady MC, Mariot C, Descatha A, Leclerc A, Raimbeau G, Goldberg M, Imbernon E. 2008. Attributable risk of carpal tunnel syndrome according to industry and occupation in a general population. *Arthritis Rheum* 59: 1341–1348. [PubMed: 18759264]
- Roquelaure Y, Ha C, Pelier-Cady MC, Nicolas G, Descatha A, Leclerc A, Raimbeau G, Goldberg M, Imbernon E. 2008. Work increases the incidence of carpal tunnel syndrome in the general population. *Muscle Nerve* 37: 477–482. [PubMed: 18236454]

- Roquer J, Cano JF. 1993. Carpal tunnel syndrome and hyperthyroidism. A prospective study. *Acta Neurol Scand* 88: 149–152. [PubMed: 8213060]
- Shiri R, Varonen H, Heliövaara M, Viikari-Juntura E. 2007. Hand dominance in upper extremity musculoskeletal disorders. *J Rheumatol* 34: 1076–1082. [PubMed: 17343320]
- Shiri R, Miranda H, Heliövaara M, Viikari-Juntura E. 2009. Physical work load factors and carpal tunnel syndrome: a population-based study. *Occup Environ Med*. 66: 368–373. [PubMed: 19451144]
- Silverstein B, Adams D. 2007. Work-related musculoskeletal disorders of the neck, back, and upper extremity in Washington State, 1997–2005 SHARP technical report number 40-11-2007: Safety and Health Assessment and Research for Prevention, Washington State Dept. of Labor and Industries, Olympia, WA.
- Silverstein B, Fan ZJ, Smith CK, Bao S, Howard N, Spielholz P, Bonauto D, Viikari-Juntura E. 2009. Gender adjustment or stratification in discerning upper extremity musculoskeletal disorder risk? *Scand J Work Environ Health* 35: 113–126. [PubMed: 19294319]
- Silverstein BA, Fine LJ, Armstrong TJ. 1986. Hand wrist cumulative trauma disorders in industry. *Br J Ind Med* 43: 779–784. [PubMed: 3790459]
- Silverstein BA, Fine LJ, Armstrong TJ. 1987. Occupational factors and carpal tunnel syndrome. *Am J Ind Med* 11: 343–358. [PubMed: 3578290]
- Silverstein BA, Fan ZJ, Bonauto DK, Bao S, Smith CK, Howard N, Viikari-Juntura E. 2010. The natural course of carpal tunnel syndrome in a working population. *Scand J Work Environ Health* 36: 384–393. [PubMed: 20352175]
- Solomon DH, Katz JN, Bohn R, Mogun H, Avorn J. 1999. Nonoccupational risk factors for carpal tunnel syndrome. *J Gen Intern Med* 14: 310–314. [PubMed: 10337041]
- Stevens JC, Sun S, Beard CM, O’Fallon WM, Kurland LT. 1988. Carpal tunnel syndrome in Rochester, Minnesota, 1961 to 1980. *Neurology* 38: 134–138. [PubMed: 3336444]
- Stevens JC. 1997. AAEM minimonograph #26: the electrodiagnosis of carpal tunnel syndrome. American Association of Electrodiagnostic Medicine. *Muscle Nerve* 20: 1477–1486. [PubMed: 9390659]
- Tanaka S, Wild DK, Seligman PJ, Behrens V, Cameron L, Putz-Anderson V. 1994. The US prevalence of self-reported carpal tunnel syndrome: 1988 National Health Interview Survey data. *Am J Public Health* 84: 1846–1848. [PubMed: 7977933]
- Violante FS, Armstrong TJ, Fiorentini C, Graziosi F, Risi A, Venturi S, Curti S, Zanardi F, Cooke RM, Bonfiglioli R, Mattioli S. 2007. Carpal tunnel syndrome and manual work: a longitudinal study. *J Occup Environ Med* 49: 1189–1196. [PubMed: 17993922]
- Werner RA, Franzblau A, Albers JW, Armstrong TJ. 1998. Median mononeuropathy among active workers: are there differences between symptomatic and asymptomatic workers? *Am J Ind Med* 33: 374–378. [PubMed: 9513644]
- Werner RA, Franzblau A, Gell N, Hartigan AG, Ebersole M, Armstrong TJ. 2005. Incidence of carpal tunnel syndrome among automobile assembly workers and assessment of risk factors. *J Occup Environ Med* 47: 1044–1050. [PubMed: 16217245]
- Werner RA. 2006. Evaluation of work-related carpal tunnel syndrome. *J Occup Rehabil* 16: 207–222. [PubMed: 16705490]
- Zyluk A. 2013. Carpal tunnel syndrome in pregnancy: a review. *Pol Orthop Traumatol* 78: 223–227 [PubMed: 24104526]

Table 1.

Demographics and personal factors

Total N=2981	N	CTS Cases	OR	95% CI
Age (years)				
50+	709	90	3.07	(1.97–4.79)
35–50	1675	170	2.38	(1.57–3.62)
<35	597	27	1.00	
Gender				
Female	1572	191	1.89	(1.46–2.44)
Male	1409	96	1.00	
Race/Ethnicity				
Hispanic	579	45	0.77	(0.55–1.10)
African American	231	28	1.27	(0.83–1.95)
Asian	164	9	0.53	(0.27–1.07)
Other	88	11	1.31	(0.68–2.52)
Caucasian	1549	152	1.00	
Education				
Some High school or less	566	43	0.74	(0.53–1.04)
High school Graduate or above	2381	237	1.00	
Obese (BMI ≥30)				
Yes	1058	154	2.29	(1.79–2.93)
No	1906	132	1.00	
General Health				
Fair or Poor	342	42	1.21	(0.83–1.77)
Good	1059	118	1.08	(0.82–1.43)
Excellent or Very Good	1051	109	1.00	
Medical Conditions *				
Yes	362	59	2.04	(1.49–2.78)
No	2614	228	1.00	
Previous Distal Upper Extremity Disorder				
Yes	335	76	3.48	(2.56–4.73)
No	1877	146	1.00	
Smoking Status				
Current	787	74	1.10	(0.82–1.48)
Previous	573	71	1.50	(1.11–2.03)
Never	1601	138	1.00	

* Diabetes Mellitus, Rheumatoid Arthritis, Thyroid Disease, or Pregnancy

Bold indicates statistically significant at 5% error.

Table 2.

Binary analyses on recreation, psychosocial, and work factors *

	N	Cases	OR	95% CI
Recreational Hand Intensive Activity				
>3 hours/week	1590	165	1.64	(1.18–2.28)
≤3 hours/week	812	54	1.00	
Recreational Aerobic Activity				
>3 hours/week	626	89	1.43	(1.03–1.98)
≤3 hours/week	1126	84	1.00	
Workplace Factors				
Years Worked at Enrollment				
≤1	389	33	1.15	(0.75–1.76)
1 to ≤7	1269	114	0.91	(0.69–1.20)
7+	1297	133	1.00	
Job demand				
High	917	71	1.12	(0.78–1.61)
Low	906	63	1.00	
Decision latitude				
Low	810	61	1.29	(0.90–1.86)
High	1062	74	1.00	
Supervisor or co-worker support				
Low	410	17	0.94	(0.45–1.97)
High	351	14	1.00	
Physically Exhausted after Work				
Moderate to Severely Exhausted	961	137	1.66	(1.28–2.15)
None to Slightly Exhausted	1580	135	1.00	
Mentally Exhausted after Work				
Moderate to Severely Exhausted	682	84	1.21	(0.91–1.60)
None to Slightly Exhausted	1875	194	1.00	
Job Satisfaction				
Poorly Satisfied	420	60	1.56	(1.09–2.24)
Satisfied	1349	129	0.95	(0.71–1.27)
Very Satisfied	827	85	1.00	
Receiving Job Training				
None to Little	291	29	1.22	(0.78–1.90)
Some to A lot	1224	103	1.00	
Work shift				
Day	2467	257	1.79	(0.77–4.18)
Swing	311	19	1.50	(0.58–3.91)

	N	Cases	OR	95% CI
Rotating or Night	118	6	1.00	

* Odd ratios (OR) adjusted for age, gender, obesity, and research sites.

Bold indicates statistically significant at 5% error.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Table 3.

Multivariable analyses on physical exposures at job level*

	Cutpoints	CTS Cases	% Cases	OR	95% CI
Duty cycle					
Forceful exertions, % time					
	>32	85	9.0	1.50	(1.06–2.12)
	>11 to 32	111	11.4	1.69	(1.23–2.32)
	11	82	9.1	1.00	
All exertions, % time					
	>76	94	10.8	0.91	(0.66–1.26)
	>60 to 76	92	11.4	1.08	(0.78–1.48)
	60	92	10.7	1.00	
Force					
Worker Borg CR-10					
	>4	112	14.0	2.04	(1.45–2.88)
	>2.5 to 4	88	10.4	1.23	(0.86–1.75)
	2.5	65	7.5	1.00	
Analyst Borg CR-10					
	>4	88	9.0	1.32	(0.96–1.82)
	>2.5 to 4	88	12.3	1.42	(1.04–1.96)
	2.5	102	8.8	1.00	
Repetition					
Repetition, Forceful exertions (per min)					
	>10	110	10.0	1.45	(1.03–2.04)
	>3 to 10	90	10.9	1.21	(0.89–1.64)
	3	78	8.7	1.00	
Repetition, All exertions (per min)					
	>25	100	11.3	1.33	(0.93–1.91)
	>13 to 25	95	11.9	1.13	(0.82–1.57)
	13	83	9.7	1.00	
Analyst HAL rating					
	>6	62	12.3	1.33	(0.96–1.82)
	>4 to 6	119	10.3	1.12	(0.80–1.57)
	4	98	8.1	1.00	
Composite indexes					
Analyst HAL-TLV					
	>0.78	90	10.2	1.74	(1.27–2.39)
	>0.56 to 0.78	64	11.4	1.36	(0.91–2.02)
	0.56	119	8.7	1.00	

	Cutpoints	CTS Cases	% Cases	OR	95% CI
Posture					
Wrist Extension 30°, % time					
	>14	99	10.5	1.03	(0.71–1.48)
	>1.5 to 14	87	10.3	1.30	(0.91–1.86)
	1.5	91	9.0	1.00	
Wrist Flexion 30°, % time					
	>3	80	10.4	1.09	(0.8–1.49)
	>0 to 3	75	8.3	1.25	(0.9–1.74)
	=0	122	10.8	1.00	
Vibration					
	Yes	127	13.8	1.71	(1.28–2.29)
	No	131	8.2	1.00	

* Time weighted average. Odd ratios (OR) adjusted for age, gender, obesity, medical conditions and research sites.

Bold indicates statistically significant at 5% error.