ERGONOMIC RISK FACTORS AND CUMULATIVE TRAUMA DISORDERS

Final Report for NIOSH/CDC Grant No. R01-OH02941

November 11, 1997

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Numerous studies have shown a relationship between various physical stressors and upper extremity musculoskeletal disorders (UEMSDs). It is generally agreed that a dose-response relationship exists between exposure to these stressors and the prevalence or incidence rates of these disorders. Most of these epidemiological studies, however, have only examined exposures in a binary classification, either present/absent or low/high (Figure 1).

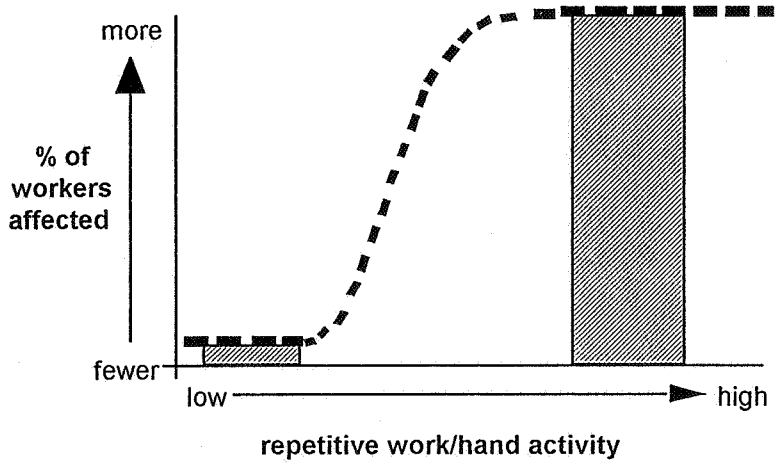

Figure 1: Proposed exposure-response curve for upper extremity musculoskeletal disorders

Thus, there is evidence to support the extremes of an exposure-response curve for the various stressors, but there is relatively little information concerning the increased risk associated with intermediate exposure levels. Part of the reason for this lack of information is the difficulty in quantifying exposure to these stressors. Repetition has been among the most widely studied of these stressors, yet no universal definition or quantification technique exists for it. The present study was designed with the primary goal of providing more information on the shape of the dose-response curve for hand repetition with respect to specific medical outcomes.

A cross sectional study was conducted in which workers' exposure to repetition and other physical stressors was quantified using a standardized observational method based on a 0 to 10 rating scale, and analyzed in conjunction with the prevalence of various upper limb disorders. Jobs were selected based on pre-determined levels of hand repetition.

Standardized medical evaluations were performed on all participating workers, and included a self-administered questionnaire, physical exam, and limited electrodiagnostic studies (EDS).

The research plan for this project included the following objective and specific aims:

"The overall objective of this cross-sectional investigation is to study jobs and perform medical screening of workers who are at risk of developing upper extremity cumulative trauma disorders (CTDs) with the goal of modeling quantitative dose-response relations between generic job exposures and medical outcomes. Specific objectives include:

1. To identify jobs with at least three levels of repetition and with at least 20 workers in each category in [each of] the study plants.

2. To quantitatively assess job exposures for repetitiveness and other factors which are known to be potential risk factors for developing CTDs, including force, mechanical stress, posture, vibration and temperature extremes.

3. To perform medical screening of subjects/workers that would include: questionnaire surveys (demographic information, pertinent medical history, occupational history, discomfort/symptom survey), standardized physical examinations of the upper extremities, nonaversive quantitative sensory tests of the upper extremities, strength testing, and limited electrodiagnostic testing of the upper extremities.

4. To model relationships between indices of job exposure (e.g. quantitative rating of repetitiveness) and indices of medical outcomes (e.g. symptoms, physical examination findings, quantitative sensory test results, electrodiagnostic test results, and prevalence of specific CTDs) with the goal of developing quantitative, dose-response relationships between job exposures and medical outcomes.

5. To compare the efficacy of the various medical screening techniques employed to detect CTDs (e.g. to compare the predictive value of quantitative sensory scores in the distal upper extremities to electrodiagnostic test results with regard to identification of possible carpal tunnel syndrome).

6. To make specific recommendations to participating plants and workers about how to reduce ergonomic risk factors identified during the course of this investigation. (If this cross-sectional investigation is successful, then the plants/jobs/workers studied would form the basis of a possible follow-up, prospective study whereby one could assess the medical impact of ergonomic interventions made at the conclusion of the initial cross-sectional investigation)."

Some of these objectives are focused on project performance (i.e., aims 1, 3 and 6), while others are focused on scientific questions (i.e., aims 2, 4 and 5). This final report will summarize results concerning the general scientific questions addressed by this project.

Specific Aim #2: Quantitative assessment of job exposures (See: Latko et al, 1995; Latko dissertation; and Latko et al, 1997).

Significant Findings and Usefulness of Findings: A standardized observational method for rating ergonomic job exposures, specifically hand activity, was developed, field tested, and validated in this study. In addition, the inter-rater and intra-rater reliability of this new method was assessed. This rating system was found to be sensitive to the parameters of movement frequency and recovery time in hand intensive tasks. The method can be easily applied, requiring no instrumentation and a minimum amount of training, and thus may be useful in a wide range settings. Experienced raters are able to consistently apply this method at different points in time. Related studies show that the system can be easily learned by non-experts and consistently produce results that agree with the "experts".

Specific Aim #4: Modeling relationships between job exposures and medical outcomes (See: Franzblau et al, 1995; and Latko dissertation, specifically chapter 5).

Significant Findings and Usefulness of Findings: Analyses focused on evaluating exposure-response relationships with adjustment for pertinent covariates (e.g., age, gender, anthropometry, and psychosocial covariates). Repetitiveness of work was found to be significantly associated with prevalence of discomfort in the wrist, hand, or fingers, tendinitis, and symptoms consistent with carpal tunnel syndrome as indicated on a hand diagram. There was no statistically significant relationship between repetitiveness of work and electrophysiologically-determined median nerve impairment. There was a borderline significant positive trend between hand repetition and carpal tunnel syndrome defined by EDS *and* hand diagram scores. For example, a change in repetition from 'low' to 'high', representing 5.6 units on the 0 to 10 scale, would produce an odds ratio of 2.9 for risk of tendinitis in the dominant elbow, forearm, wrist, hand or fingers, after adjustment for age, gender, anthropometry, and pertinent medical history. Similarly, shifting exposure to hand repetition from 'low' to 'high' produced an odds ratio of 2.3 for risk of CTS-like symptoms in the dominant hand, based on hand diagram scores, again, after adjustment for age, gender and other pertinent covariates. The results of this study indicate there is a definite exposure-response relationship for certain measures of UEMSDs and hand repetition, and that hand repetition can be a major contributing factor to these problems.

Specific Aim #5: To compare and evaluate various screening techniques employed to detect CTDs (See: Franzblau et al, 1994; Franzblau et al, 1997; Werner et al, 1994a; Werner et al, 1995).

Significant Findings and Usefulness of Findings: Numerous screening procedures and devices have been proposed for measuring or detecting CTDs, and, in particular, carpal tunnel syndrome (CTS) among active workers. The present study provided an opportunity to evaluate many of these techniques in greater detail than ever before.

(Franzblau et al, 1994) Four hundred and eleven workers from 4 different companies participated in a worksite screening program designed, in part, to estimate the prevalence of carpal tunnel syndrome (CTS). Each worker completed a discomfort survey and underwent limited nerve conduction testing of the median and ulnar sensory nerves in both wrists. The discomfort survey included a hand diagram which allowed subjects to shade in area(s) affected by numbness, burning, tingling, or pain. The discomfort survey also asked each worker to indicate whether she or he had experienced neuropathic symptoms (i.e., numbness, burning, tingling, or pain) in the wrist, hand or fingers of each hand, without regard to localization (i.e., median versus ulnar versus radial distribution), and also nocturnal occurrence of symptoms. Analyses involved comparing hand diagram scores and non localized wrist/hand/finger symptoms with electrodiagnostic test results. All configurations of hand diagram scores of the dominant hands had a statistically significant association with electrophysiologically determined median nerve dysfunction, but so did non localized symptom reports. The sensitivity, specificity, and positive predicted values of hand diagrams were poorer than those reported previously. While some test performance characteristics of hand diagrams were better than those for non localized distal extremity symptoms consistent with CTS, some were worse. This was the largest study of the utility of hand diagram scores ever published. Overall, our data suggest that hand diagrams are no better than using a questionnaire to determine if workers have experienced symptoms consistent with CTS in their wrists, hands or fingers without regard to localization. The choice of screening tool would depend on the goal of screening, in particular, whether it is more desirable to have slightly higher sensitivity or positive predictive value. While the overall test performance characteristics of hand diagrams were acceptable for epidemiological purposes, the relatively low positive predictive values for hand diagrams (relative to an electrodiagnostic 'gold standard') clearly point to the limitation of trying to use this screening device for identifying individual workers in need of further clinical evaluation (i.e., there would be too many false positive results).

(Franzblau et al, 1997) Efforts to understand or to monitor upper extremity musculoskeletal disorders among workers usually have involved use of questionnaires. The goal of this study was to assess the test-retest reliability of an upper extremity discomfort questionnaire among industrial workers. The test-retest reliability of the questionnaire used to elicit demographic information, medical history, exercise participation, and musculoskeletal symptom-related information among industrial workers appears to be good to excellent in most instances. This study is the largest, and most appropriately analyzed study (employing kappa statistic analyses) of its kind. These results suggest that most results of this discomfort questionnaire are reliable, and suitable for use in epidemiological studies.

(Werner et al, 1994a; Werner et al, 1995) Various automated vibrometry devices, single frequency and multiple frequency, have been promoted as possible screening devices for carpal tunnel syndrome among workers at risk of this disorder. A significant weakness of previous studies which have employed vibrometry devices is that almost all have been based on highly selected patient or clinical populations, rather than randomly selected workers, which is the study group of interest. Use of patient or clinical populations usually results in substantial 'spectrum bias', and serves to inflate the test characteristics (i.e., sensitivity, specificity, positive predictive value, and/or negative predictive value) of these devices. The present study afforded an opportunity to evaluate these devices among randomly selected active workers, and thus to assess their efficacy at identifying possible median sensory nerve impairment in the population of interest (i.e., workers).

Results for both single frequency and multiple frequency vibrometry indicate that among randomly selected active workers both procedures have, at best, a weak association with traditional electrodiagnostic measurements of median sensory nerve function at the wrist. Furthermore, the degree of association with electrodiagnostic measurements never exceeded that found for a symptom survey and/or hand diagram. Thus, one can achieve equivalent or better results (i.e., sensitivity, specificity, positive predictive value, and negative predictive value) using a self-administered questionnaire, rather than these psychophysical devices. Hence, it is our recommendation that such devices should not be used for the purpose of screening for median nerve impairment, or CTS, in worker populations.

Additional Pertinent Results Based on Results from this Study:

Vitamin B6 and Carpal Tunnel Syndrome (Franzblau et al, 1996). Case reports and small case series have suggested that vitamin B6 deficiency is an important etiologic factor in carpal tunnel syndrome (CTS). To address this question we examined 125 randomly selected active workers from 2 industrial plants. Each worker completed a self-administered symptom questionnaire, and underwent electrodiagnostic testing of the median and ulnar (sensory) nerves. Laboratory biochemical analyses of vitamin B6 status were also performed using the erythrocyte glutamic pyruvic transaminase (EGPT) assay, and quantification of plasma pyridoxal 5'-phosphate (PLP). Measurements of vitamin B6 status were unrelated to self-reported symptoms potentially consistent with CTS, or electrophysiologically-determined median or ulnar nerve function. These results suggest that CTS among active industrial workers is unrelated to vitamin B6 deficiency. Furthermore, empirical prescription of high doses of vitamin B6 to patients with CTS is unwarranted and potentially hazardous (i.e., vitamin B6 is a well known neurotoxin at pharmacological doses).

Screening Nerve Conduction Studies for Predicting Future Carpal Tunnel Syndrome (Werner et al, 1997a). Using traditional 'cut-offs' for defining electrodiagnostic

abnormalities for the median nerve at the wrist ('median mononeuropathy') we have found that up to 25% of workers are 'abnormal', and that *most* such workers do not report symptoms consistent with CTS in the wrists, hands or fingers. In an effort to gain a better understanding of the implication of these findings, and their natural history, we conducted a prospective case-control study. Cases were workers with asymptomatic median mononeuropathy in one or both hands. Controls were asymptomatic workers without median mononeuropathy, and were matched to cases on age, gender, and place of employment. Cases and controls were followed for a mean of 17 months (minimum 10 months, maximum 24 months), at which point they were solicited to report whether they had experienced onset of symptoms potentially consistent with CTS since having the electrodiagnostic tests performed at 'baseline'. No electrodiagnostic testing was performed at follow-up. Approximately two-thirds of cases and controls responded to the follow-up symptom survey. The results demonstrated that there was no difference in the onset of CTS-like symptoms among cases and controls. Furthermore, only 10% to 12% of cases and controls developed such symptoms during the follow-up period. Thus, the overwhelming majority of subjects with asymptomatic median mononeuropathy remained asymptomatic during the follow-up period. In a multivariate logistic model with 'symptoms at follow-up' as the dependent variable, and which included covariates for electrodiagnostic measurements, demographic parameters, duration of follow-up, and ergonomic exposures (specifically hand repetition), the only covariates which were significant, or approached significance, were ergonomic exposure and duration of follow-up. These results would suggest that a finding of asymptomatic median mononeuropathy is not a pre-clinical precursor of CTS. More practically, these results indicate that basing employment decisions on pre-placement/post-offer electrodiagnostic screening test results for CTS are invalid and probably discriminatory.

Influence of Body Mass Index and Work Activity on the Prevalence of Median Mononeuropathy at the Wrist (Werner et al, 1997b). The purpose of this study was to determine the relative influence of certain risk factors (work activity (industrial versus clerical), body mass index (BMI), and demographic factors) on the prevalence of median mononeuropathy at the wrist, and if there were interactions among these risk factors. This was a cross-sectional study of workers at five different work sites; four were industrial sites and one was clerical. Five hundred twenty-seven workers were recruited - 164 clerical and 363 industrial. The presence of median mononeuropathy in either hand was measured by electrodiagnostic techniques comparing median and ulnar sensory peak latencies. Thirty percent of workers in this study had an abnormality of the median sensory nerve at the wrist (34% of the industrial versus 21% of the clerical workers). The adjusted risk for industrial workers was twice that of clerical workers. Obese workers (BMI > 29) were four times more likely to present with a median mononeuropathy than workers who were normal or slender (BMI < 25). There were no significant interactions between BMI and work site in relation to median mononeuropathy. Increasing age was also related to an increased risk of median mononeuropathy. Overall, obesity, industrial

work, and age are independent risk factors that influence the prevalence of median mononeuropathy among active workers.

Median mononeuropathy among active workers: are there differences between symptomatic and asymptomatic workers? (Werner et al, in press). The objective of this study was to determine if symptomatic workers with an abnormal sensory nerve conduction study consistent with carpal tunnel syndrome differed, in terms of electrophysiologic measures, psychosocial, demographic, anthropometric, or ergonomic variables, from workers with an asymptomatic median mononeuropathy. This was a cross-sectional study of active workers at 6 different work sites. Cases were defined as workers with electrodiagnostic findings of a median mononeuropathy in either hand based upon a 0.5msec prolongation of the median sensory evoked peak latency compared to the ulnar latency. This group was stratified on the basis of symptoms of numbness, tingling, burning or pain in the hand. The two groups were compared in terms of demographic, anthropomorphic, psychosocial. electrophysiologic and ergonomic risk factors.

Active workers from 6 different sites were tested; five sites involved manufacturing workers and 1 site represented clerical workers. There were 184 active workers with a median mononeuropathy in one or both wrists documented on nerve conduction studies. These workers represented a subset of over 700 workers screened at 6 different locations. The main outcome measure was each patient's report of symptoms of pain, numbness, tingling or burning in the hand or fingers that lasted more than one week or occurred 3 or more times in the 12 months preceding the initial screening. Analyses suggest that workers with a median mononeuropathy who complained of hand symptoms were more likely to be female, have jobs with higher hand repetition levels, have higher ratings of job security, not have a history of diabetes, use more force in their job with more abnormal postures of their fingers, and wrist and have a trend toward a more prolonged median sensory distal latency. Most logistic regression models explained less than 15% of the variance (pseudo R2).

Overall, women with jobs that have higher ergonomic risks and no history of diabetes were more likely to have reported symptoms associated with carpal tunnel syndrome compared to other workers with a documented median mononeuropathy. Psychosocial variables were not particularly discriminatory. None of the models allow enough precision to predict on an individual basis.

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