

3. JOURNAL ARTICLES AND CONFERENCE PROCEEDINGS *by*

NIOSH authors may appear in either U.S. or foreign journals, books, or symposia. This list, in alphabetical order by author, includes the bibliographic information to permit retrieval of the references from university or public libraries.

1. Baron S, Habes D [1992]. **Occupational musculoskeletal disorders among supermarket cashiers.** *Scandinavian Journal of Work, Environment and Health* 18(2)(Suppl):127-129.

An evaluation was performed of musculoskeletal disorders experienced by supermarket cashiers, and recommendations were offered for redesigning the workstation to eliminate the problem. The four stores chosen for study were owned by a supermarket chain and had a variety of checkout counter designs. The study population included 119 female cashiers and 55 other female supermarket workers who participated in the medical study portion of the research. An additional 41 workers, 9 of whom were cashiers, participated in telephone interviews. An ergonomic evaluation was conducted by analyzing videotapes of cashiers processing normal customer orders and a standard cart order of 33 common items. The results of the study indicated that there was an association between working as a cashier and developing musculoskeletal disorders. Other supermarket workers also had ergonomic stresses in their jobs. The measured association was therefore deemed to be an underestimation of the true relative risk of work as a cashier compared with the work of people with few ergonomic stressors.

2. Bernard B, Sauter S, Fine L, Petersen M, Hales T [1992]. **Psychosocial and work organization risk factors for cumulative trauma disorders in the hands and wrists of newspaper employees.** *Scandinavian Journal of Work, Environment and Health* 18(2)(Suppl):119-120.

The relationship of psychosocial factors and work organization to cumulative trauma disorders of the hands and wrists was investigated among newspaper employees using video display terminals. The study sample included 971 employees who completed a questionnaire dealing with demographics, work history, job tasks performed, workstation design and equipment used, and work organization, psychosocial scales, and upper extremity musculoskeletal discomfort. The univariate analyses revealed many significant associations between work organization and psychosocial variables and cumulative trauma disorders of the wrist and hand. However, the importance of these variables was diminished somewhat in the final logistic regression model where several job task and demographic variables emerged as important predictors of these disorders. Those which remained important in the final analysis included social support variables and job variance. When the analyses were performed within specific departments, the work organization and psychosocial variables were better predictors of cumulative trauma disorders of the hand and wrist in those departments with a larger number of clerical and data entry video display terminal users. Work organizational and psychosocial variables were not significant factors in the editorial department.

3. Burt S [1991]. **Carpal tunnel syndrome among employees at a window hardware manufacturing plant. Health hazard evaluation series.** American Association of Occupational Health Nurses Journal 39(12):576-577.

Carpal tunnel syndrome (CTS) was evaluated among workers in the assembly department of a window hardware manufacturing facility. The facility manufactured window balance systems from stamped, rolled aluminum or vinyl. Twenty-eight female employees on five assembly lines were studied in relation to CTS, Guyon's canal syndrome, and tendinitis. The annual incidence rate for the disorders was 23.4 per 200,000 hours worked. Repetitiveness, strongly associated with CTS and other cumulative trauma disorders, was assessed through cycle or subcycle time and manual manipulations. Muscular exertion (force) was evaluated subjectively except for two tasks in which a calibrated force gauge was used. All twelve assembly jobs involved CTS risk factors; eight were highly repetitive. Extreme postures were also involved in all of the jobs in the assembly department. A job rotation policy in effect at the time of the study was unsuccessful because the jobs involved similar risk factors. The author recommends that the jobs classified as highly repetitive be shared by more workers or slowed down. Relocation of parts, use of appropriately designed holding bins, and product transporting conveyors are recommended to correct extreme postures. Two specially designed hand tools could be improved by addition of longer, larger, padded handles and a different angle. Better parts design and quality control are also recommended to facilitate assembly.

4. Estill C, Grant K [1995]. **The use of wrist monitors to quantify wrist movements.** In: Proceedings of the Sixth US-Finish Joint Symposium on Occupational Health and Safety, People and Work, Research Reports 3, Espoo, Finland. Helsinki, Finland: Finish Institute of Occupational Health, pp. 142-145.

Cumulative trauma disorders (CTDs) have become very common among workers in industry. The U.S. Bureau of Labor Statistics reports that of the 368,300 occupational illness cases in 1991, 233,600 cases were associated with repeated trauma. Hand and wrist repetitive trauma illnesses account for a large proportion of those injuries. The National Occupational Exposure Survey conducted by NIOSH in 1981 to 1983 projected that 4,034,474 workers in the U.S. were potentially exposed to hand and wrist chronic trauma. Repetitive motion injuries of the hand and wrist include carpal tunnel syndrome, tendinitis, tenosynovitis, De Quervain's syndrome, trigger finger, ganglionic cysts, pronator syndrome, and Guyon tunnel syndrome. Ergonomic risk factors for carpal tunnel syndrome may include frequent deviation from neutral wrist position, frequent use of the "pinch" grasping hand position, repetitive wrist and hand movements, and extreme and forceful wrist positions. A wrist which is extremely flexed or extended, especially with strong finger exertion, results in more pressure in the carpal tunnel. The relation of flexion and extension to pressure in the carpal tunnel was studied by Armstrong and Chaffin, who showed that the force within the wrist can be directly related to the angle of the wrist. Quantification of wrist positions and number of repetitions is needed to determine the causes of hand and wrist disorders. Many researchers have resorted to cinematographic

methods to determine wrist postures and repetitions. These methods require the use of at least two cameras and are time consuming. Other methods of quantifying wrist positions, repetitions, and even velocity and acceleration exist. Two of these methods are described here along with their advantages and disadvantages.

5. Fine L, Silverstein B, Armstrong T, Anderson C, Sugano D [1986]. **Detection of cumulative trauma disorders of upper extremities in the workplace.** *Journal of Occupational Medicine* 28(8):674-678.

The following aspects of surveillance of upper extremity cumulative trauma disorders (UECTDs) in the workplace were discussed: possible objective and specific features; use of preexisting data sources (PDSs); and use of questionnaire and physical examination (QPE) data. The main objective was identification of jobs with elevated rates of disorders. Causal determinants were also identified. To assess the utility of PDSs, PDS data from three large automobile manufacturing plants in the Midwestern United States were analyzed. Sensitivity of QPE in detecting UECTDs diagnosed in existing occupational medical records kept by a fourth plant was determined using a primary questionnaire, supplemental symptomatic questionnaires, and physical examination. Jobs were identified that had statistically elevated incidence density ratios (IDRs), using either medical absence or medical case data. Limitations included a striking difference in the plant-wide incidence rates depending on which source was examined. The experience with surveillance questionnaires and physical examination suggested that this approach could be adapted for routine surveillance and would be superior to the use of PDSs. The sensitivity of the QPE approach was 93.7 percent, the specificity was 47.9 percent, and the positive predicted validity was 54.1 percent. The large number of false positives observed was probably due to the fact that the most sensitive definition of cumulative trauma disorder was used. If the false positive workers who never sought treatment were

excluded, the adjusted specificity improves to 73 percent and the positive predictive validity to 81 percent.

6. Frederick L, Habes D, Schloemer J [1984]. **An introduction to the principles of occupational ergonomics.** *Occupational Health Nursing* 32(12):643-645.

The principles of occupational ergonomics were considered by addressing: the definition and goals of occupational ergonomics; the prevention of ergonomic health problems; hazard identification; preventive health programs; and evaluation of interventions and programs. The focus of this communication was on the prevention and control of the two major categories of occupational health problems affecting the musculoskeletal and peripheral nervous systems. The first was upper extremity cumulative trauma disorders associated with repetitive and forceful hand and wrist movements. The second related to muscle strain and fatigue due to static muscular work. A sample ergonomic checklist was included to assist in identification of potential workplace hazards. The authors conclude that the occupational nurse is uniquely able to recognize, evaluate, and control ergonomic hazards and take part in preventing them. Enhanced performance of basic nursing functions of promoting health and preventing illness and injury was associated with knowledge and application of the principles of ergonomics.

7. Grant K, Congleton J, Koppa R, Lessard C, Huchingson R [1992]. **Use of motor nerve conduction testing and vibration sensitivity testing as screening tools for carpal tunnel syndrome in industry.** *Journal of Hand Surgery* 17(1):71-76.

The usefulness of motor nerve conduction testing and vibration sensitivity testing for screening industrial workers for carpal tunnel syndrome (CTS) was evaluated. The study group consisted of 47 female comparisons, 47 females employed

at a fiberglass manufacturing facility who had no symptoms of CTS, 16 females employed at the facility who had CTS symptoms, and 22 patients (32 hands) with physician-diagnosed CTS. The subjects were tested with the Nerve Pace electroneurometer, that measured median motor nerve conduction time, and the Vibration-II, an instrument that measured sensitivity to a 120 hertz (Hz) vibration. The mean median nerve conduction time in the comparisons was significantly lower than in the other groups. The mean conduction time in the asymptomatic workers was significantly lower than in the two CTS groups. The mean vibration sensory threshold in the CTS patients was significantly higher than in the other groups. The thresholds in the comparisons and industrial workers with and without CTS symptoms did not differ significantly from each other. More than 85% of the hands in the comparisons had median nerve conduction times and vibration thresholds that were less than one standard deviation from the mean. Only 34% and 28% of the CTS hands had nerve conduction times and vibration thresholds, respectively, less than one standard deviation above the comparison mean. When compared across all nerve conduction time groups, vibration thresholds were significantly elevated only in hands that had nerve conduction times at least three standard deviations above the comparison group mean. False positive rates were 5% to 15% and false negative rates were 28% to 59%. The authors conclude that motor nerve conduction appears to be a more sensitive indicator of changes associated with CTS than the 120 Hz vibration threshold. The high false negative rates associated with the tests limit their usefulness as screening tools for CTS.

8. Grant K, Habes D [1993]. Effectiveness of a handle flange for reducing manual effort during hand tool use. *International Journal of Industrial Ergonomics* 12(3):199-207.

The effectiveness of adding a flange to handles on reducing grip force requirements when using hand tools was examined. The study group consisted of 30 right-handed male volunteers, 18 to 30 years

old, free of musculoskeletal problems. Half of the subjects grasped and lifted 2.5 by 1.3 by 14 centimeter rectangular aluminum bar handles with or without a flange located at the top of the handle (lifting task). The other 15 subjects grasped and pulled similar handles with or without a flange located on the bottom (pulling task). The handles in both experiments were instrumented with a strain gauge and connected to load cells. Each experiment was performed at three levels of weight (load cell resistance). Grip forces were recorded and expressed as a percentage of the maximum voluntary contractile (MVC) forces which were measured in a preliminary experiment. Electromyographic (EMG) activity recorded from the flexor pollicis longus, flexor digitorum superficialis, and extensor digitorum muscles of the forearms was monitored. In each experiment, increased load cell resistance produced corresponding increases in force exertion. In the lifting task, average grip forces ranged from 6.6% to 19.2% of MVC and peak grip forces ranged from 12.4% to 32.7% of MVC. In the pulling task, average and peak grip forces varied from 5.1% to 11.6% and 12.6% to 21.6%, respectively. The presence of the flange did not significantly affect peak or average grip force in either experiment. The lifting task was associated with significantly higher levels of EMG activity than the pulling task. The presence of the flange did not significantly affect forearm muscle EMG activity. The authors conclude that placing a flange on the handle does not significantly reduce the grip force required to perform the examined lifting or pulling tasks.

9. Grant K, Habes D, Hales T, Daniel W [1993]. Biomechanical hazards in a jewelry manufacturing facility. *Applied Occupational and Environmental Hygiene* 8(2):90-96.

Cumulative trauma disorders (CTDs) often afflict workers whose jobs require stereotyped, repetitive movements; awkward postures; forceful exertions; and exposure to hand-transmitted vibration. High prevalence rates of CTDs have been associated with a number of occupations, including butchers

and meat packers, auto workers, garment makers, postal workers, and VDT operators, whose work tasks have many of the aforementioned features. Occupational hazards presented to jewelry workers (SIC-3911) have been previously described. Recognized hazards include exposure to toxic substances and noise. Jewelry workers are also at high risk of physical injury from working with improperly guarded machine tools and power presses. Nonetheless, the biomechanical hazards presented to jewelry workers have not been well characterized, despite evidence that jewelry workers are at significant risk for upper extremity CTDs. The purpose of this article is to describe the results of a detailed ergonomic survey conducted at a jewelry manufacturing facility. The survey was conducted by NIOSH in response to a Hazard Evaluation and Technical Assistance (HETA) request by management. Plant management requested help in identifying and resolving potential biomechanical hazards after a review of their injury and illness records (OSHA 200 logs) for the years 1988-1990 revealed seven CTD cases among plant employees. This article describes the hazards identified during this survey and presents general recommendations to reduce these hazards.

10. Grant K, Habes D, Putz-Anderson V [1994]. **Psychophysical and EMG correlates of force exertion in manual work.** *International Journal of Industrial Ergonomics* 13(1):31-39.

The use of electromyography (EMG) and psychophysical rating of perceived exertion (RPE) as predictors of grip force in dynamic tasks was examined and compared. The subjects were 45 males ages 18 to 30, who were all right-handed and did not have any musculoskeletal impairments. Subjects performed two work tasks. The first was a material transfer task in which a 3.8 centimeter diameter cylindrical handle was grasped and moved from one side of a circular platform to another side. In this task, the mass and shape of the handle were altered. The second task was an assembly operation task, in which a cylindrical handle suspended from a rope was

gripped and pulled downward. In this experiment, the rope tension and handle shape were altered. Right forearm EMG were monitored using surface electrodes placed over the flexor pollicis longus, flexor digitorum superficialis, and extensor digitorum muscles using a Therapeutics Unlimited model 544 EMG system. Grip force was measured using a strain gage mounted in the handle. The Borg CR/10 rating scale was used to access perceived exertion. The results indicated that in all experiments, EMG and RPE correlated strongly and positively with grip force. Neither EMG or RPE alone was a consistently better predictor of grip force. The authors conclude that psychophysical rating methods such as the RPE may be suitable alternatives to EMG measurements for estimating force in manual work because of its simplicity and convenience.

11. Grant K, Habes D, Putz-Anderson V, Baron S, Sweeney M, Piacitelli L, Fine L [1993]. **Ergonomic evaluation of checkstand designs in the retail food industry: a preliminary report based on expert assessment.** *Applied Occupational and Environmental Hygiene* 8(11):929-936.

A study was conducted on the relationship between the design of checkstands in retail food establishments and the development of upper extremity cumulative trauma disorders in workers. Investigators from NIOSH evaluated side, front, right hand take away, over the counter, and over the end type checkstands with different scanner, scale, conveyor belt, and bag stand arrangements. Thirteen different checkstands were evaluated by having experts rate the biomechanical stress placed on eight body areas during different work activities. The front checkstand configuration was chosen as the type presenting the least biomechanical stress to the cashier as well as stands that allowed for the use of both hands by the checker for scanning and bagging and those that used an input belt. The height of the scanner was found to be a design feature that influenced the stress on the lower back and shoulders. Other features that were judged to be desirable were

input conveyors that brought the items directly to the edge of the scanner, narrow conveyor belts, scanners that allowed items to slide over the scanner, a combined scanner/scale, easy accessibility to the bag stand, and a bag stand placed 13 to 17 inches below the checkstand surface.

12. Grant K, Habes D, Steward L [1992]. **An analysis of handle designs for reducing manual effort: the influence of grip diameter.** *International Journal of Industrial Ergonomics* 10(3):199-206.

The effect of handle diameter on manual effort in a simulated assembly task was investigated. The study group consisted of 16 right-handed male volunteers, mean age 22.8 years. Right hand length, breadth, and inside grip diameter were measured. Maximum voluntary contraction (MVC) strength of the right hand and forearm were measured using standard isometric test techniques. The subjects performed a simulated industrial assembly task using three handles: a handle with diameter matched to the inside grip diameter of the subject (fit diameter), a handle diameter 1.0 centimeters (cm) smaller than the fit diameter, and a handle having a diameter 1.0 cm larger than the fit diameter. Grip force and electromyographic activity of the forearm muscles were noted. Manual effort was evaluated by comparing the force exerted on the handle during the tasks to the maximum force generating capacity. The greatest grip forces were exerted when the smaller handle was used. Maximum grip strength increased 39% on the average for each 1.0 cm decrease in handle diameter. Peak and average grip force exertion were not significantly affected by handle diameter, but did vary directly with resistance imposed by the handle and test apparatus. The electromyographic data indicated that muscle effort increased with

increasing handle diameter. The authors conclude that small changes in handle diameter, on the order of +/-1.0 cm, can have significant effects on manual effort. It may be beneficial to manufacture tools with different sized handles to allow users with larger and smaller grips than normal to select handles best suited for their hand size.

13. Grant K, Habes D, Steward L [1992]. **The influence of handle diameter on manual effort in a simulated assembly task.** In: Kumar S, ed. *Advances in Industrial Ergonomics and Safety IV.* New York, NY:Taylor and Francis, pp. 797-804.

This study evaluated the effect of three cylindrical handle diameters on manual effort in a simulated assembly task. Sixteen right-handed men participated in the study. A simulated industrial workstation was designed for the study consisting of a height adjustable chair and table positioned in front of a free standing pulley system. When seated the subject's knees were bent at about 90 degrees and the feet were flat on the floor. The handle was positioned about 43.2 centimeters above the table, in a sagittal plane with the participant's right shoulder. Participants grasped the handle with the right hand and pulled it down to a target marked on the work table. The results demonstrated that even a small change in handle diameter of plus or minus 1.0 centimeters can have significant effects on manual effort. A handle which allows some overlap between the thumb and forefinger may be better for some applications than a larger handle. The authors suggest there may be a benefit to manufacturing tools with different sized handles to allow users with larger and smaller grips to select handles best suited for their hand size. The relationship between handle size and anthropometric dimensions should be an important consideration in future handle evaluations.

14. Grant K, Johnson P, Galinsky T [1993]. **Use of the actigraph for objective quantification of hand/wrist activity in repetitive work.**

In: Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting, Vol. 2, Seattle, WA. Sacramento, CA:Human Factors Society, pp. 720-724.

The extent to which physical differences in two specific jobs can be reflected in actigraph data was examined. Actigraphs were affixed to the wrists and ankles of workers to determine if changes in activity levels paralleled activity differences noted through direct observation and videotape analysis. The two jobs studied were grocery cashiers and general merchandise clerks. Ten grocery cashiers and four general merchandise clerks participated in the study. Data were collected over an 8-hour period. Clear differences in the activity patterns were recorded for the two workers. The high levels of wrist activity and low levels of ankle activity recorded by the cashier differed from the moderate levels of wrist activity and high levels of ankle activity recorded by the clerk. The authors conclude that actigraphy provided some advantages over traditional observational methods for quantifying work-related hand/wrist activity. However, they also note that in most cases the quantitative facts determined from the actigraphic measurements need the qualitative determinations from visual observations made during the work study.

15. Haartz J, Sweeney M [1995]. **Work-related musculoskeletal disorders: prevention and intervention research at NIOSH.**

In: Proceedings of the Sixth US-Finish Joint Symposium on Occupational Health and Safety, People and Work, Research Reports 3, Espoo, Finland. Helsinki, Finland:Finish Institute of Occupational Health, pp. 135-141.
(A copy of this article is in Part I, pages 7-13.)

16. Habes D [1987]. **CTS precludes simple solutions [letters].** Occupational Health and Safety 56(2):68.

The author critiques an article by John A. Sebright entitled "Gloves, Behavior Changes Can Reduce Carpal Tunnel Syndrome." The author found that the article was lacking in supporting evidence and was contrary to findings in the cited literature. Splints and gloves, rather than a benefit, are an increased risk factor for carpal tunnel syndrome (CTS) in machine operators. The editor, citing Dr. Sebright, states that the latter uses splints in the workplace only occasionally, when the employee can wear them comfortably, but that he utilizes cock/up night splints on a regular basis. Dr. Sebright agrees with Mr. Habes that the article under discussion could possibly mislead employers about the value of wrist splints on the job as a means of controlling CTS.

17. Habes D, Carlson W, Badger D [1985]. **Muscle fatigue associated with repetitive arm lifts: effects of height, weight and reach.** Ergonomics 28(2):471-488.

Metabolic costs and the pattern of upper extremity muscular fatigue for arm lifts were examined to test the hypothesis that for jobs requiring upper extremity lifts, the vertical and horizontal location of the end point of the lift are as important as the object weight. The tests were conducted with 5 healthy males, 22 to 34 years of age, inexperienced at industrial lifting jobs. The repetitive task, at five lifts per minute, was to grasp a weighted cylinder in each hand, assemble them into one unit, and place the unit on a rack. A 1-hour test series was performed for several height and reach distances and cylinder weights. Upper body fatigue was measured by electromyography (EMG) and tests of strength decrement. Whole body fatigue was assessed using heart rate, oxygen uptake, and measures of perceived fatigue.

Muscle fatigue was assessed by changes in amplitude and frequency of the EMG signal. Heart rate, oxygen consumption, and static strength were measured before and after the lifting sessions. The experimental design included eight test conditions; one condition was run per day and at least 2 days elapsed between test conditions. Muscle fatigue results showed 32.2 and 14.7 percent average increases in the EMG amplitude for the 80 and 40 percent maximum voluntary contraction (MVC) weight conditions, respectively. The percentage decrease in static strength as a function of task conditions was 9.5 and 5.9 percent for the 80 and 40 percent MVC weight conditions, respectively. The effect of height was most significant on the biceps. The critical task condition was reach. The authors conclude that there are physiological bases for avoiding extreme reach and height, especially for weights in the range of 80 percent MVC. Because weight is a significant variable, an acceptable weight should be less than 80 percent MVC for all heights and reaches. Tasks should avoid combining excessive weight and reach requirements, heavy loads and extreme heights, or weights above 40 percent MVC along with excessive reach and height.

18. Habes D, Putz-Anderson V [1985]. The NIOSH program for evaluating biomechanical hazards in the workplace. *Journal of Safety Research* 16(2):49-60.

The NIOSH program for evaluating biomechanical hazards in the workplace was discussed. The Hazard Evaluation and Technical Assistance (HETA) program was described. The HETA program was originally authorized by the Occupational Safety and Health Act of 1970. Although the program was intended originally only for investigating toxic substances in the workplace, it has been broadened to include physical and biomechanical hazards. Sources of requests for biomechanical hazard evaluations were described. Through 1984, NIOSH has responded to 20 requests for evaluation of musculoskeletal disorders stemming from

biomechanical hazards. Of these, 16 were received from companies engaged in light to medium manufacturing involving repetitive tasks, two were received from food handling and processing companies, one from a company that transports and stores bulk commodities, and one from a service and installation company. Trends in the number of requests for biomechanical evaluations were discussed. Procedures for conducting a biomechanical HETA were reviewed. Developing recommendations for interventions was considered. Such recommendations are prescriptive statements that define a course of action for preventing or reducing biomechanical trauma and involve two basic approaches, utilizing administrative and engineering controls. Examples of interventions to reduce musculoskeletal injuries were given. A number of indirect effects have suggested that NIOSH has achieved some success in achieving prevention and control of musculoskeletal injuries. The program has created and reinforced an awareness of the problems and the need for creative solutions.

19. Hales T, Nathan P [1991]. Occupation as a risk factor for impaired sensory conduction of the median nerve at the carpal tunnel [letters]. *Journal of Hand Surgery* 16B(2):230-232.

Commentary and response were provided on an article by Nathan et al. (*Journal of Hand Surgery* 13B(2):167-170, 1988) concerning occupational hand use and median nerve conduction slowing. In a letter to the editor, Hales contested that the research actually supported an association between occupational hand activity and slowing of nerve conduction at the carpal tunnel. Comparison of the exposure variables of repetition and force to nerve conduction results was not employed; rather, Nathan et al. compared occupational grouping to nerve conduction results. Impairment of sensory conduction as influenced by length of employment, and severity of slowing with regard to occupational hand activity and previous carpal tunnel surgery were also contested. In rebuttal, Nathan states that the

commentary ignores or minimizes certain important findings related to intergroup differences and follow up data which confirms a lack of association between hand use group and the prevalence of slowing. Nathan concludes that there is little objective evidence that the hand activities studied cause the conduction defect underlying carpal tunnel syndrome, but indicates that such hand use exacerbates the symptoms of carpal tunnel syndrome.

20. Hales T, Sauter S, Peterson M, Fine L, Putz-Anderson V, Schleifer L, Ochs T, Bernard B [1994]. **Musculoskeletal disorders among visual display terminal users in a telecommunications company.** *Ergonomics* 37(10):1603-1621.

A cross sectional study of 518 telecommunications employees (mean age 38) using video display terminals (VDTs) was performed in order to assess the relationship between workplace factors and work-related upper extremity (UE) disorders. UE disorders were divided into four groups: neck, shoulder, elbow, and hand/wrist. Workers in three cities were selected for study, two with high UE disorder prevalence and one with low prevalence. Participation was voluntary. Questionnaires and physical examinations defined the cases of UE disorders among five categories of workers utilizing VDTs: Directory Assistance Operators (DAO), Service Representatives (SR), Loop Provisioning (LP), Recent Change Memory Administration Center (RCMAC), and Mail Remittance (MR). Information on demographics, individual factors (preexisting medical conditions and recreational activities), work organization and practices, and psychosocial aspects of work (including electronic performance monitoring) were obtained. Multiple logistic models assessed the relationships between workplace factors and UE disorders. The descriptive statistics were divided into two categories: musculoskeletal disorders and independent variables. For the musculoskeletal disorders group, 22% (111 subjects) of the participants met the case definition of UE disorders. LP employees had the

highest prevalence of UE disorders (36%), followed by RCMAC (25%), DAO (22%), MR (20%), and SR (6%). Tendon-related disorders were the most common UE disorder type; the hand and wrist area was the most affected of the tendon related disorders, followed by neck, elbow, and shoulder areas. Independent variables included aspects of race and gender. The psychosocial environment may also contribute to UE disorders; fear of being replaced by computers, increasing work pressure, and workload surges were among the psychosocial variables considered in the study. The authors suggest that work-related UE disorders are common among telecommunications workers who utilize VDTs, and emphasize the importance of psychosocial variables to the occurrence of UE disorders.

21. Henning R, Sauter S [1991]. **Work-physiological synchronization and well-being in a repetitive task.** In: *Proceedings of the Human Factors Society 35th Annual Meeting, Vol. 1, San Francisco, CA.* Sacramento, CA:Human Factors Society, pp. 781-784.

The relationship between work and biological rhythms during the performance of repetitive data entry tasks was evaluated. Twenty experienced female data entry workers aged 18 to 40 years performed data entry tasks under 12 work rhythm conditions. Tests measuring cardiac responses, respiratory sinus arrhythmias (RSA) in the heart rate, and changes in lung volume were administered at the end of each 40-minute work period, along with a mood survey. Synchronization of work and breathing rhythm could predict reduced heart rate using multiple regression analysis. Work and RSA synchronization were predictive of reduced boredom and work, and breathing and RSA synchrony could predict reduced heart rate. The authors conclude that synchronization between work and biological rhythms can increase the well being of workers, as well as their adjustment to the performance of repetitive tasks.

22. Henning R, Sauter S, Salvendy G, Krieg E [1989]. **Microbreak length, performance, and stress in a data entry task.** *Ergonomics* 32(7):855-864.

The efficacy of scheduled microbreaks in controlling fatigue in a highly repetitive computer task was evaluated. Twenty experienced female data entry operators (mean age, 27.4 years) participated in the study. On each of 2 days, subjects worked at a data entry task for three 40-minute periods each morning and afternoon. After each 20 minutes of work, a self-regulated microbreak was given, lasting until the subject felt ready to continue work. Microbreak length was measured by the computer, and subject's mood was monitored by a survey administered at the beginning of each 40 minute period. Task performance was measured as keystroke output, error rate, and self-correction rate, and subject heart rate and interbeat interval were continuously monitored. Mean microbreak duration was 27.4 seconds. Keystroke output was reduced and correction rate increased, both significantly, between the first and second halves of each work period. No change in error rate or the cardiac parameters was observed. Long microbreak duration predicted low correction rates and longer mean interbeat intervals in the second half of the work period. High first half correction rates were predictive of long microbreak length. Long microbreaks were associated with the mood indicators fatigue and boredom. Within each three period session, significant variation was found in microbreak duration, cardiac response, and mood indicators. The authors conclude that microbreak duration is positively correlated with worker perception of fatigue, although the efficacy of scheduled microbreaks of discretionary duration may be limited in combating fatigue.

23. Jensen R, Klein B, Sanderson L [1983]. **Motion-related wrist disorders traced to industries, occupational groups.** *Monthly Labor Review* 106(9):13-16.

A request was made by the American Federation of State, County and Municipal Employees to examine reasons for diagnoses of carpal tunnel syndrome and tendinitis occurring in the wrists of clerical workers at the Minneapolis Police Department (SIC-9221). Police transcribers are responsible for typing all pertinent information relating to arrests made by law enforcement officers. The typed copies are made on multi-carbon report forms. When completed, the copies are hand separated and distributed into mail boxes for dissemination to other areas. Of the 33 clerk/typists available, 10 were full-time police transcribers covering 3 shifts, 7 days a week. Ergonomic measurements were taken from 12 employees of the transcription, homicide, and juvenile departments during normal operating hours. In general, those individuals who reported symptoms were found to type with their wrists in extension (24 degrees) beyond the normal typing position of 10 to 15 degrees. Employees who had been employed for shorter periods of time in the transcription department appeared to be at the greater risk for wrist problems. It is recommended that wrist rests be provided for the typists. Chairs should also be of the kind where quick adjustment of the seat height and the height and angle of the back support are possible. Typing tables must be adjustable in height, have adequate knee clearance horizontally and vertically, and adequate surface areas for the typewriter and documents being processed.

24. Lee K, Swanson N, Sauter S, Wickstrom R, Waikar A, Mangum M [1992]. **A review of physical exercises recommended for VDT operators.**
(A copy of this article is in Part I, pages 97-118.)

25. McGlothlin J [1988]. **An ergonomics program to control work-related cumulative trauma disorders of the upper extremities.** Dissertation, University of Michigan, 134 pp.

A program was established in a hand intensive manufacturing facility to control upper extremity cumulative trauma disorders (CTDs). The plan consisted of four distinct components: job analysis; education and training of management and workers in the principles of ergonomics and identification of risk factors; development of a task force; and implementation of a health surveillance system. The control approach indicated that facility designed tools were the most successfully implemented attribute, followed by changes in work practices to reduce work stresses. The original program stressed administrative controls including worker rotation, job enlargement and market available tools, while the plan for new jobs stressed engineering controls such as work station design, gravity feed racks, and facility designed tools. The shift from administrative to engineering controls may be attributed to application of ergonomic principles by facility engineers during the design of new workstations, flexibility in production quotas during the work startup phase, and financial resources for ergonomic enhancements to new work stations after startup. The author concludes that the best time to implement ergonomic suggestions is during work station design and start up; that the success of retrofitting existing work stations by ergonomic design depends on the support of management and labor at all levels; and that any long term effectiveness of the task force is a direct function of key management and labor support.

26. McGlothlin J [1995]. **Ergonomic Intervention for the Soft Drink Beverage Industry.** In: Proceedings of the International Ergonomics Association (IEA) World Conference 1995 [in press].

An ergonomic study of 9 soft drink beverage driver-salesworkers (ages 34 to 58) was conducted

over a 4-month period. Field evaluations of the truck and delivery process showed the beverage container lifting tasks exceeded the recommended weight limit (RWL) when judged against the NIOSH lifting criteria. Metabolic demands were also high, especially during peak delivery periods. Ergonomic interventions were implemented, such as pullout steps, external grab handles, multiple height shelving in truck bays, and substitution of plastic for glass beverage containers. The engineering interventions, in combination with improved work practices, reduced multiple handling of beverage cases and decreased awkward postures during beverage handling.

27. Nelson R [1987]. **Prevention - a government perspective.** *Ergonomics* 30(2):221-226.

A government perspective on prevention of musculoskeletal disorders as perceived by NIOSH was presented. NIOSH identified ten leading work-related disorders; two of these disorders were chronic musculoskeletal and acute trauma disorders caused by exposure to manual load handling, repetitive motion, or vibration. Short and long term objectives of the NIOSH musculoskeletal injury prevention strategy were described. Low back injury, the leading musculoskeletal disorder in the United States, was discussed. Etiology and prevention of musculoskeletal disorders were considered. NIOSH research strategy from the perspective of the Division of Safety Research in the development of effective prevention strategies for occupational musculoskeletal disorders was presented. Selected occupational safety research topics were highlighted. The topics included clinical investigation, the NIOSH low back evaluation system, laboratory investigations, and field investigations. NIOSH field studies on back injuries were reviewed.

28. Nestor D, Bobick T, Pizatella T [1990]. **Ergonomic evaluation of a cabinet manufacturing facility.** In: Proceedings of the Human Factors Society 34th Annual Meeting, Vol. 1, Orlando, FL. Sacramento, CA: Human Factors Society, pp. 715-719.

The results of a detailed ergonomic evaluation of a cabinet manufacturing facility were presented. The report was the result of a NIOSH Health Hazard Evaluation made at the request of the management. The facility employed about 450 full-time workers (425 union, 25 salaried), and consisted of a 300,000 square foot area in 3 different buildings. Data generated by the facility's safety and ergonomics program, as well as its computerized injury surveillance system, for the period January 1986 through December 1988 were used. A factory tour was also undertaken to collect biomechanical and ergonomic data, and to identify hazards. The methodology included videotaping workers (36 tasks); measuring workstations, static force exertions, manually handled weights, and pushing force exertions; and interviewing workers at risk for injury. Of the 36 tasks, 17 major tasks were reviewed (the other 19 were variations of the 17), and a taxonomy of selected operations was developed with respect to injury risk. Analysis of the company's injury statistics revealed a total of 276 OSHA reportable injuries during the period under review. Of these, 135 (49%) were lacerations, bursitis, tendinitis, or numbness of upper extremities, or sprains/strains (other than back); 58 (21%) were back sprains/strains; and less than 10% each were lower extremity, head/neck, or eye injuries. Of the injuries, 70% were sustained during the first year of employment at the factory, 43% in the first 6 months, 16% in the first month, and 10% on the first day. Manual materials handling operations at the defect saw cut table had the highest rates of injury (7.8 and 6.8/100 workers). Cabinet lifting and transport cart and stacking bank pushing tasks also required controls to reduce injury risks. Recommendations were made based on ergonomic considerations to minimize risk factors associated

with sustained postures overexertion, lifting/carrying, sudden movements, and repetitive motion.

29. Orgel D, Milliron M, Frederick L [1992]. **Musculoskeletal discomfort in grocery express checkstand workers. An ergonomic intervention study.** *Journal of Occupational Medicine* 34(8):815-818.

An ergonomic intervention study of musculoskeletal problems in grocery express checkstand workers was conducted by NIOSH in response to a request. Preliminary interviews were conducted with seven employees who used the checkstand. Most of the symptoms were clustered in the neck, upper back, and shoulder. Workers attributed their symptoms to design features of a newly installed checkstand that caused them to adopt awkward postures and to use twisting motions to operate it. An ergonomic analysis of the express checkstand was performed. In order to bring groceries from the far corner of the checkstand to the scanning area the employee had to make an extended reach. The keyboard was awkwardly positioned. This caused the operator to adopt awkward positions to operate it and to move the groceries across the scanner at the same time. Moving the items to the front of the belt across the scanner caused a high rate of repetitive motion for the dominant hand. A baseline survey of 23 cashiers who used the express checkstand and a regular checkstand was conducted. All 23 cashiers experienced neck, upper back, or shoulder pain when using the express checkstand. Only ten subjects reported discomfort when they used the regular checkstand. The express checkstand was modified by placing a physical barrier near the front corner to prevent the cashier from overreaching and to reduce trunk flexion. An adjustable keyboard was installed. This helped reduce static shoulder strain. A training videotape was shown to the cashiers to instruct them in how to avoid potentially stressful postures. A follow up survey conducted 4 months

later indicated that 15 of 19 subjects experienced discomfort when operating the express checkstand. Only 26% required medication for their discomfort versus 78% before the intervention, a statistically significant improvement. The authors conclude that the intervention process was effective in reducing the employees symptoms. Employees are good sources of information when performing these types of interventions.

30. Putz-Anderson V [1988]. Cumulative trauma disorders: A manual for musculoskeletal diseases of the upper limbs. (The Table of Contents, Abstract, and ordering information for this publication are contained in Part I, pages 89-96.)

31. Putz-Anderson V [1988]. Prevention strategies adopted by select countries for work-related musculoskeletal disorders from repetitive trauma. In: Aghazadeh F, ed. *Trends in Ergonomics/Human Factors V, Proceedings of the Annual International Industrial Ergonomics and Safety Conference*, New Orleans, LA. New York, NY:Elsevier Science Publishers, pp. 601-611.

Preventive strategies adopted by various countries for work-related musculoskeletal system disorders were discussed. The terminology and background of musculoskeletal system disorders were summarized. Changes in work patterns and the workforce and their relation with musculoskeletal system disorders were considered. The mechanization and automation of work have shifted biomechanical stresses from the back to the upper limbs. This shift, combined with increasing pace and repetitiveness due to assembly lines and automated pacing, has led to a sharp increase in the incidence of cumulative trauma disorders. The availability of national incidence data for cumulative trauma disorders was considered. Strategies for preventing cumulative trauma disorders practiced in Sweden, Australia,

Great Britain, and the United States were reviewed. Sweden and Australia have enacted legislation that provides recommendations for good ergonomic work practices. The Health and Safety Act in Great Britain provides for a broad range of legal obligations which are supported by codes of practice, standards, and guidance material. Although repetitive strain injuries to the upper limbs are not included in Great Britain's current reporting system, musculoskeletal problems are recognized as a significant occupational health problem by the Medical Division of the Health and Safety Executive. In the United States there are no special ordinances or Occupational Safety and Health Administration (OSHA) standards for cumulative trauma disorders. The National Institute for Occupational Safety and Health has issued a strategy document [see Part II, page 155] that focuses on developing a plan for preventing work-related cumulative trauma disorders. The plan provides for better surveillance and diagnostic information for identifying cumulative trauma disorders, developing predictive models, expanding the role of the public and private sectors to implement ergonomic interventions, and disseminating user oriented guides to labor, management, and the OSHA field staff.

32. Putz-Anderson V [1988]. The impact of automation on musculoskeletal disorders. In: Karwowski H, Parsaei R, Wilhelm M, eds. *Ergonomics of Hybrid Automated Systems I, Proceedings of the First International Conference on Ergonomics of Advanced Manufacturing and Hybrid Automated Systems*, Louisville, KY. New York, NY:Elsevier Science, pp. 1-7.

The impact of automation on musculoskeletal system disorders was discussed. The rationale for using automated systems in industry was considered. The relationship between repetitive jobs and cumulative trauma disorders (CTDs) was discussed. The overall prevalence of CTDs is not known; however, research has indicated that a significant amount of lost work time and high labor turnover can be attributed to upper limb

injuries. More than half of the United States workforce has a repetitive job that has the potential for developing CTDs. The relationship between modern technology and automation and CTDs was discussed. Automation relieves workers of heavy lifting and potentially hazardous work by shifting the biomechanical stresses from the trunk to the upper limbs. This has resulted in lighter work loads but a significant increase in work pacing accompanied by less recovery time for muscles, tendons, and ligaments involved in short cycle, manually intensive work. Tasks requiring high rates of repetitive motion require more muscle effort than less repetitive tasks. The increased concentration of repetitive forces on the ligaments, tendons, muscles, and nerves of the hands, wrists, and arms has increased the risk of CTDs, particularly tenosynovitis and humeral tendinitis. The CTD risk is also increased by the worker having to adopt awkward postures due to technical designs developed to achieve work economy and simplification. CTDs associated with stressful postures include tenosynovitis of the flexors and extensors of the forearm and those arising from extreme flexion and extension of the wrist. Nonoccupational factors associated with CTDs such as physical size, strength, previous injuries, and joint alignment were discussed. The author concludes that highly repetitive work combined with awkward postures increases the risk of developing CTDs. The recommended solution for reducing the risk involves redesigning the tools and tasks to reduce biomechanical and repetitive stresses on the musculoskeletal system.

33. Putz-Anderson V, Doyle G, Hales T [1992]. **Ergonomic analysis to characterize task constraint and repetitiveness as risk factors for musculoskeletal disorders in telecommunication office work.** *Scandinavian Journal of Work, Environment and Health* 18(2)(Suppl):123-126.

An expanded activity analysis was developed to characterize the task functions of clerical workers in telecommunications. The analysis focused on task repetitiveness and task constraint as risk

factors since both attributes have been identified as contributing to the development of cumulative trauma disorders. The following five jobs were considered: directory assistance operators, centralized mail remittance employees, service representatives, employees of a recent change memory administration center, and employees of a loop provisioning center. Workers from each of the job categories at 3 job sites were videotaped during 7 to 20 job cycles. Each of 66 samples of work was reviewed using a video recorder editor system. Several risk groups were established from the data collected. The directory assistance operators, service representatives, and centralized mail remittance workers had task constraint ratios above 0.80. Service representatives and centralized mail remittance workers had longer cycle times than directory assistance.

34. Putz-Anderson V, Galinsky T [1993]. **Psychophysically determined work durations for limiting shoulder girdle fatigue from elevated manual work.** *International Journal of Industrial Ergonomics* 11(1):19-28.

Work durations for limiting shoulder girdle fatigue from elevated manual work were determined using a psychophysical approach. The influence of the rate of repetitive work on fatigue limiting work durations and how it might influence and interact with that of other tasks were of particular interest. Participants were 72 right-handed individuals (35 males and 37 females) free of known musculoskeletal problems. Minor anthropometric differences were accommodated. A Baltimore Therapeutic equipment work simulator was used for the repetitive motion task in which the seated subject grasped the tool handle and performed a task consisting of repeated lifting and lowering of the handle, and striking a metal pointer to a metal plate at the end of each excursion. Each cycle consisted of a 180 degree arcing movement to lift the handle, and a similar movement to lower it. Repetition rate was controlled by an electronic timer. Subjects assessed perceived discomfort on the Borg CR-10 scale. A series of four experiments were

conducted. Results showed that subjects were able to adjust work trial durations to attain each of three experimentally set levels of perceived arm/shoulder discomfort. Increases in force output requirement from 10 to 20 to 30% maximum voluntary contraction produced significant corresponding decreases in work trial duration. Increases in discomfort led to increasing reductions in work time as a function of force. Average trial durations associated with varying levels of work demand ranged from 29 to 160 seconds. The largest effects on work duration were by rate and force of movement, while reach height and tool weight had comparatively minor impact. Males tended to engage in longer work trials than females. The authors conclude that rate and force of movement are critical to the development of shoulder and arm fatigue, and discuss the possible role of gender related experimental demand characteristics.

35. Ridyard D, Bobick T, Starkman B [1990]. **Ergonomics awareness training for workplace design engineers.** *Applied Occupational and Environmental Hygiene* 5(11):771-781.

An ergonomically based awareness training program for workplace design engineers was described. The purpose of the program, which was developed for the facilities and processing departments of Merck and Company, Incorporated, West Point, Pennsylvania was to provide its engineers with a practical working knowledge of the principles of ergonomic job design. The main objective of the program was to ensure that these principles were used by design engineers to eliminate risk factors associated with back injuries, carpal tunnel syndrome, and other cumulative trauma disorders from the workplace. The program consisted of a 3-hour training session in which lectures with slides and demonstrations by a certified industrial hygienist examined ergonomic hazards associated with repetitive hand and wrist activities, such as container labeling and inspection and using poorly designed tools. After the session the attendees were given checklists to use while designing new

facilities, process work areas, and job tasks. The authors note that the engineers at the facility are currently using the checklists. Feedback from the engineers 6 months after the training program revealed that the checklists are an effective method for communicating ergonomic concepts in a clear and concise format. They recommend that basic ergonomic and human factor concepts be incorporated into designs for new facilities, processes, work areas, or job tasks.

36. Seligman P, Matte T [1991]. **Case definitions in public health.** *American Journal of Public Health* 81(2):161-162.

Case definitions and their relevancy to public health were discussed. The results of a recent case surveillance study of carpal tunnel syndrome (CTS) were summarized to illustrate the importance of defining criteria for case reporting and the differences between surveillance and clinical case definitions. Of 78 patients with upper extremity pain or paresthesia who were diagnosed with CTS on the basis of changes in median nerve conduction latency, only 68% were correctly diagnosed using symptoms, signs, and work histories. These clinical case criteria, when used separately, generally had high sensitivity but low specificity. The components of a medical surveillance program were discussed. These included detecting and reporting cases, analyzing and synthesizing the reports that have been received, and providing an appropriate response to the reports. Defining the cases carefully can facilitate each of the components. It was noted that for occupational illness surveillance, the critical issue is developing a case definition that will assist in identifying workplaces that require investigation and remediation. Any case definition used should have high sensitivity and should be easily applied to cases reported by primary care clinicians and specialists. The authors conclude that creating and applying appropriate surveillance case definitions can help bridge the gap existing between occupational and infectious disease surveillance.

37. Silverstein B, Fine L [1991]. **Cumulative trauma disorders of the upper extremity. A preventive strategy is needed.** *Journal of Occupational Medicine* 33(5):642-644.

Support was offered from clinical, laboratory, and epidemiological studies that cumulative trauma disorders may be caused, aggravated, or precipitated by forceful, repetitive, or sustained static activities, particularly in combination with awkward postures occurring over time with insufficient recovery time. Several prospective studies have been recently reported which were cited as supporting this thesis. Possible limitations of these studies were briefly described. Of the 20 facilities visited, initial walk-through surveys revealed that 7 of these facilities did not have enough active workers in jobs in each of the 4 exposure categories. Subject selection included being an active worker who worked currently and for at least one year before the study, on a job that met one of four categories of hand force and repetitiveness. Because only active workers who had been on one of the study jobs for at least one year before the study were included the prevalence of cumulative trauma disorders were probably underestimated. The results did not note a strong association between the measures of hand force and repetitiveness and disorders of the neck, shoulder, or elbow/forearm. Since upper extremity postures were not considered in the exposure categorization, it was possible that someone in a low force low repetitive job may have been exposed to other potential work-related risk factors such as extreme postures or localized mechanical stress against soft tissues.

38. Snook S, Fine L, Silverstein B [1988]. **Musculoskeletal disorders.** In: Levy B, Wegman D, eds. *Occupational Health - Recognizing and Preventing Work-Related Diseases*, Chpt. 22. Boston, MA: Little, Brown and Company, pp. 345-370.

An overview of work-related musculoskeletal disorders commonly involving the back, cervical spine, and upper extremities was presented with a

framework for recognizing and preventing these problems. Specifics covered relating to low back pain included the pathophysiology of musculoskeletal disorders; signs and symptoms of injury including lumbar insufficiency, lumbago, and sciatica; diagnosis of injury; high risk jobs; management; prognosis; and control. Discussion of prevention of low back pain included the use of mechanical aids, optimum work level planning, good workplace layout, sit and stand work stations, and appropriate packaging to match object weights with human capabilities. Work-related disorders of the neck and upper extremities were described with schematic representation of pathophysiology of these disorders, treatment, and preventive strategy. Control of repetitiveness, forcefulness, awkward posture, vibration, mechanical stress, and cold may reduce risk.

39. Sommerich C, McGlothlin J, Marras W [1993]. **Occupational risk factors associated with soft tissue disorders of the shoulder: a review of recent investigations in the literature.** *Ergonomics* 36(6):697-717.

Recent studies on occupational risk factors for soft tissue disorders of the shoulder region were reviewed. The problem of work-related shoulder pain was considered. Shoulder pain resulting from soft tissue cumulative trauma ranks second in clinical frequency to low back and neck pain as occupationally related musculoskeletal disorders. The prevalence of shoulder pain across a wide range of occupations has been found to range from 4% to 42%. Problems associated with investigating occupational risk factors for soft tissue shoulder disorders were discussed. The types and clinical characteristics of soft tissue shoulder disorders were described. These included tendon-related disorders, muscular shoulder pain, nerve-related disorders, neurovascular disorders, and occupational cervicobrachial disorder. Tendon-related disorders constituted a general category that included rotator cuff tendinitis, calcific tendinitis, bicipital tendinitis, tendon tear, and bursitis. Nerve and neurovascular disorders usually

involved inflammation or compression of the suprascapular nerve. Occupational cervicobrachial disorder was a symptom complex located primarily in the shoulder and neck region. Epidemiological, field, and laboratory studies of risk factors for occupational shoulder pain were discussed. These have indicated that awkward or static postures, heavy physical labor, direct load bearing, repetitive arm movements, working with the arms held above the shoulders, and lack of rest breaks are significant risk factors for shoulder pain. Personal risk factors include female sex, job dissatisfaction, age, social factors such as having a sick spouse, having children and working a shift different from that of the spouse, and participating in sports activities such as swimming, tennis, and baseball pitching. Shoulder pain has been shown to be related to elevated electromyographic (EMG) activity and changes in EMG level and median spectral frequency of the trapezius muscle. Suggested engineering and administrative controls for reducing occupational risk factors for soft tissue shoulder disorders were discussed.

40. Tanaka S, McGlothlin J [1989]. A conceptual model to assess musculoskeletal stress of manual work for establishment of quantitative guidelines to prevent hand and wrist cumulative trauma disorders (CTDs). In: Mital A, ed. *Advances in Industrial Ergonomics and Safety I*. New York, NY: Taylor and Francis, pp. 419-426.

A conceptual model intended to serve as a prototype for developing guidelines for preventing wrist tenosynovitis was described. The model was developed by assuming that flexion at the wrist reduced the carpal tunnel size, and tensions applied to the flexor tendons during wrist flexion significantly increased pressure in the carpal tunnel. A physiological limit for synovial lubrication of tendon sheaths, which permit smooth gliding of the tendons, was postulated to exist. If this limit was exceeded as a result of forceful movements of the hand and fingers, this could trigger an inflammatory response in the affected tendon sheath unit. It was assumed that

friction between the tendon and tendon sheaths in the carpal tunnel was the major factor responsible for aggravating tenosynovitis regardless of the type of grip or task performed by the hands and fingers. The frictional energy produced was proportional to the hand workload, frequency of the movements, and wrist angle. An equation that expressed the action limit and maximum permissible limit for a manual task as the product of the average hand and finger workload needed to complete the task (WL), the repetitiveness of the task cycle per unit time, an exponential term incorporating the wrist angle required for the task, and a constant related to the degree of protection desired was derived. The theoretical upper limit of the WL could be determined by measuring the largest force that could be exerted safely by the hand and fingers and the distance of tendon slide during the task. Suggestions for industrial surveys that could test the model were presented. The authors conclude that the model if validated could be used to evaluate the effectiveness of ergonomic interventions, provide engineers with quantitative ergonomic guidelines when planning the construction of factories, and explain the principles of manual work stressors to managers, workers, or supervisors.

41. Tanaka S, McGlothlin J [1993]. A conceptual quantitative model for prevention of work-related carpal tunnel syndrome. *International Journal of Industrial Ergonomics* 11(3):181-193.

A conceptual mathematical model of work-related carpal tunnel syndrome (CTS) useful for establishing guidelines for preventing CTS was discussed. The authors postulate that friction between the tendons and tendon sheaths in the carpal tunnel is the most important factor for initiating or aggravating tenosynovitis which is regarded as a precursor to CTS and that the frictional energy is proportional to the product of the internal force required to do the work, the repetitiveness of the movements, and the wrist angle. Preventing the initial tenosynovitis could prevent CTS. Assuming that hand or wrist pain is

associated with compression of the median nerve, it was further postulated that preventing the onset of hand pain or discomfort would prevent tenosynovitis and CTS. A mathematical equation describing the internal musculoskeletal forces exerted by the finger/hand/wrist/forearm complex, the repetitiveness of the task cycle per unit time, and the wrist angles that must not be exceeded for a specific task to prevent wrist or hand pain was derived. The values for the internal musculoskeletal forces, task repetitiveness, and wrist angles could be obtained from controlled human experiments. The authors conclude that the model can be used to establish quantitative guidelines for preventing job-related tenosynovitis and CTS.

42. Tanaka S, Seligman P, Halperin W, Thun M, Timbrook C, Wasil J [1988]. Use of workers' compensation claims data for surveillance of cumulative trauma disorders. *Journal of Occupational Medicine* 30(6):488-492.

A study of the risk of developing cumulative trauma disorders (CTDs) was conducted to evaluate workers' compensation claims as a means of identifying workplaces at high risk of CTDs. All claims filed with the Ohio Bureau of Workers' Compensation over the period 1980 through 1984 were reviewed to identify CTD cases. Incidence rates for CTD were computed. The data were analyzed to determine industries and occupations with the highest risk of CTD. A total of 6,849 cases of CTD originating from 3,242 employers were identified. Tenosynovitis due to continuous motion was the most frequent diagnosis, accounting for 58.3 percent of the cases. The wrist was the most frequently affected body part, accounting for 48.4 percent of the cases. Women had consistently higher incidence rates for CTDs than males for all age groups. The highest rate for females occurred in the 36 to 45 age group. The overall incidence rate for CTDs was 4.1 cases per 10,000 workers for females and 2.3 cases/10,000 for males. The annual number of CTD cases reported increased nearly threefold between 1980 and 1984. This increase was due

primarily to increases in cases of tenosynovitis. Approximately 40 percent of the lost workdays was due to injuries resulting in 30 to 60 days disability. The highest rates (in cases/10,000) of CTDs occurred in the manufacture of transportation equipment (17.7), furniture (12.8), leather articles (12.4), electronic and electric equipment (11.8), rubber products (11.6), and food products (11.3). Over 60 percent of the cases occurred among fabricators, assemblers, machine operators, and miscellaneous machine operations. The authors conclude that analyzing workers' compensation claim data is an effective surveillance method for identifying occupations posing a high risk of CTDs.

43. Tanaka S, Wild D, Seligman P, Halperin W, Behrens V, 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):451-470.

To estimate the prevalence and work-relatedness of self-reported carpal tunnel syndrome (CTS) among U.S. workers, data from the Occupational Health Supplement of 1988 National Health Interview Survey (NHIS) were analyzed. Among 127 million "recent workers" who worked during the 12 months prior to the survey, 1.47% (95% CI: 1.30; 1.65), or 1.87 million self-reported CTS, and 0.53% (95% CI: 0.42; 0.65), or 675,000, stated that their prolonged hand discomfort was called CTS by a medical person. Occupations with the highest prevalence of self-reported CTS were mail service, health care, construction, and assembly and fabrication. Industries with the highest prevalence were food products, repair services, transportation, and construction. The risk factor most strongly associated with medically called CTS was exposure to repetitive bending/twisting of the hands/wrists at work (OR = 5.2), followed by race (OR = 4.2; whites higher than nonwhites), gender (OR = 2.2; females higher than males), use of vibrating hand

tools (OR = 1.8), and age (OR = 1.03; risk increasing per year). This result is consistent with previous reports in that repeated bending/twisting of the hands and wrists during manual work is etiologically related to occupational carpal tunnel syndrome.

44. Winn F, Habes D [1990]. Carpal tunnel area as a risk factor for carpal tunnel syndrome. *Muscle and Nerve* 13(3):254-258.

Carpal tunnel area was investigated as a risk factor for carpal tunnel syndrome (CTS). It was hypothesized that if canal area is a risk factor for the syndrome, individuals who develop the syndrome should have smaller carpal canal areas than those who remain free of the syndrome. Sixty-one subjects, approximately equally divided by sex, age group, and diagnosis, were examined. A measurement of cross-sectional areas of the carpal canal by computerized axial tomography indicated that individuals diagnosed as carpal tunnel patients had significantly larger carpal canal areas than controls. The results indicate that a small carpal canal area does not appear to be a risk factor for carpal tunnel syndrome.

45. Winn F, Krieg E [1989]. A regression model for carpal tunnel syndrome. *Proceedings of the Society for Experimental Biology and Medicine* 192(2):161-165.

The purpose of this study was to determine whether a logistic regression model for the diagnosis of carpal tunnel syndrome (CTS) could be developed. Forty-eight variables were initially identified, for the 28 CTS and 34 non-CTS subjects, including 28 measures of nerve function, 6 anatomical measurements, 8 variables relating to disease symptoms, and 6 variables relating to physical attributes. A priority clustering procedure was used to establish groups for the principal components analyses. The first principal component of each cluster was then used in a backward, stepwise logistic regression analysis.

The best combination of candidate variables, as identified by the regression equation, was Raynaud's symptoms and median nerve motor function. The results of this study indicate that a model for CTS can be generated from a set of variables and that a linear combination of variables representing nerve function is closely associated with conduction decrements resulting from CTS.

46. Winn F, Putz-Anderson V [1990]. Vibration thresholds as a function of age and diagnosis of carpal tunnel syndrome: a preliminary report. *Experimental Aging Research* 16(4):221-224.

A study of age-related changes in vibration thresholds in persons with carpal tunnel syndrome (CTS) was conducted. The cohort consisted of 34 persons diagnosed with CTS. The comparisons consisted of 34 persons with no diagnosed symptoms of nerve impairment. The age range of the subjects in both groups was 20 to 65 years. Vibration thresholds of the subjects were determined with the Optacon, an instrument that measured tactile stimulation of the index fingers of the right hand. When stratified by age, the 20 to 29 year old group contained 6 CTS patients and 10 comparisons, the 30 to 39 year old group 5 CTS patients and 11 comparisons, the 40 to 49 year age group 7 CTS patients and 6 comparisons, and the 50 to 65 year old group 9 CTS patients and 7 comparisons. Vibration thresholds of all CTS patients averaged 37% higher than those of the comparisons. Vibration thresholds in the 40 to 49 and 50 to 65 year old CTS patients and comparisons were significantly higher than in the 20 to 29 year age group. The authors conclude that screening programs for CTS that rely only on the results of vibration threshold data that do not take into account age will probably generate large numbers of false positives for workers over 40 years of age. There is need for age-adjusted norms for vibration thresholds.

4. GRANT REPORTS are generated primarily from an agreement between NIOSH and a non-governmental organization. They typically describe scientific research conducted by that organization for NIOSH. Grant reports, which are listed below in alphabetical order by author, may be published either as final reports available from NTIS or as journal articles. For journal articles, bibliographic information is provided to permit retrieval from public or university libraries.

1. Armstrong T [1981]. Investigation of occupational wrist injuries in women, terminal progress report.

GRANT NO: R01OH00679. 15 pp.

NTIS NO: PB88-247630 PRICE: Check NTIS

Occupationally caused carpal tunnel syndrome (CTS) in women was investigated through three studies: test battery development for workplace surveillance of CTS; effects of work pace, wrist splints, light duty work, and time off on CTS; and an anatomic study of the pathomechanics of CTS. The test battery included measures of median and ulnar nerve performance in the hand and wrist. Age was determined to be the most consistent and significant factor of normal subject performance. The test battery was then used to study the effectiveness of common interventions for CTS. Workers from two automobile upholstery factories were used to evaluate the effectiveness of specific changes in work pace and work with and without wrist splints. Results of the pace study tend to support the use of pacing as a control measure for occupational CTS. The use of wrist splints actually served to aggravate CTS. In a longitudinal study, seven of eight subjects demonstrated some improvements in performance corresponding to time off or light duty work; two subjects who worked overtime demonstrated a worsening of performance; and all subjects given splints showed immediate worsening of symptoms. The anatomical study revealed marked mononuclear

infiltration in vascular walls of vessels within the carpal tunnel which is similar to a pathological condition found in rheumatoid arthritis.

2. Armstrong T, Chaffin D [1979]. Carpal tunnel syndrome and selected personal attributes. *Journal of Occupational Medicine* 21(7):481-486.

GRANT NO: R01OH00679

The significance of hand and wrist size and stressful work methods in the development of carpal tunnel syndrome was studied. A group of 18 diseased female workers was compared to a group of 18 female controls. Both groups were engaged in production sewing of seat covers from heavy fabrics. Measurements of the hand and wrist, anterior and posterior radiographs, and various internal measurements representing wrist size in or around the carpal tunnel were analyzed. Internal measurements for the diseased and control groups did not differ significantly, and no association between hand size or shape and carpal tunnel syndrome was indicated. Analysis of data on hand and wrist positions and hand force recorded by cinematography and electromyography reveals that diseased subjects tended to exert more hand force and to deviate from the straight wrist position more often than controls. The authors conclude that the findings of this and other studies indicate that certain work methods are factors of occupational carpal tunnel syndrome. Further research to test alternative work methods to control the disease and to develop a model of the pathogenesis of the syndrome is recommended.

3. Armstrong T, Chaffin D [1979]. Some biomechanical aspects of the carpal tunnel. *Journal of Biomechanics* 12(7):567-570.

GRANT NO: R01OH00679

Biomechanical aspects of the human carpal tunnel were reviewed, and the relationships between forces inside flexed and extended wrists to wrist

size, hand force, and hand position were investigated. Studies have indicated that the major force producing muscles during exertions of the hand are the extrinsic finger flexor muscles. These muscles are connected to the fingers with long tendons passing through the carpal tunnel. Studies have suggested that the force between the extrinsic finger flexor tendons and the trochlea in the flexed wrist compresses the median nerve and is a factor in carpal tunnel syndrome. Direct pressure measurements at the site of the median nerve demonstrated compression of the median nerve. Synovial membranes of the radial and ulnar bursas that surround the extrinsic finger flexor tendons also are compressed by forces in both flexed and extended wrists. Repeated compression may cause synovial inflammation and swelling, compressing the median nerve inside the carpal tunnel. When the wrist is extended, a load distribution on the trochlea of the profundus tendon is about 25 percent greater in females than males. When the wrist is flexed, the load on the trochlea in females is 14 percent greater than in males. Exertions of the hand with a wrist in a greatly deviated position would result in greater total force on the tendons and trochleas than would occur with a nearly straight wrist. For a given hand force, greater forces per unit length and greater resultant forces on the tendons and trochleas would be produced in pinch than in grasp.

4. Armstrong T, Chaffin D, Foulke J [1979]. **A Method for Measuring Shapes of Anatomical Surfaces.** *Journal of Biomechanics* 12(5):397-399.
GRANT NO: R01OH00679

A three-dimensional point encoder was built to record surface geometries of hand/wrist structures during the course of study of biomechanical aspects of carpal tunnel syndrome. The encoder consists of a pointer that slides axially and rotates in perpendicular planes. It is instrumented with a linear voltage differential transformer and with two potentiometers such that voltages proportional to the axial and two angular positions

of the pointer are produced. These voltages correspond to the spherical coordinates of the pointer. Encoder voltages were measured via an analog/digital (A-D) converter and an HP 2100 computer. Each dimension of the system was calibrated by measuring the voltage differences between known positions of the pointer. The computer was then programmed to calculate spherical coordinates from A-D converter voltages of each point and then to convert the results to Cartesian coordinates. The data points were stored in a file in disc memory for later plotting and analysis. Sample point locations along the flexor digitorum profundus tendon of the second digit in three positions of a partially dissected wrist were presented. Such a data encoder should be of help to those interested in recording shapes and positions of anatomical structures.

5. Bleecker M [1986]. **Vibration perception thresholds in entrapment and toxic neuropathies.** *Journal of Occupational Medicine* 28(10):991-994.
GRANT NO: OH-07090

Use of the modified Optacon tactile stimulator for measurement of perception thresholds as an index of subclinical disease in entrapment and toxic neuropathies is reviewed. It is noted that these frequent problems encountered in occupational neurology are difficult to objectively quantify. Use of nerve conduction velocity for documenting the severity of an impairment in the peripheral nervous system is described. However, nerve conduction studies may be insensitive early in the disease process. Design of the Optacon tactile stimulator and its use are described. Studies of vibration perception threshold are cited which demonstrate an increase in these thresholds with age. Increased thresholds are also reported to correlate with peripheral neuropathy in 38 percent of subjects examined. Studies suggest that routine neurological examination and electrodiagnostic studies are more sensitive indicators of idiopathic peripheral neuropathy than vibration perception thresholds. A study of 56 alcoholic outpatients revealed diminished sensation in a glove

distribution in 62 percent of the patients and diminished sensation in a stocking distribution in 96 percent. Identification of carpal tunnel syndrome in workers exposed to neurotoxic substances or cumulative repetitive trauma of the upper extremities is discussed. Vibration perception thresholds in the compromised index finger can be compared with the ipsilateral uninvolved ulnar innervated fifth finger. As an objective measure of nerve dysfunction in carpal tunnel syndrome, the Optacon is reported to have a sensitivity of 79 percent and a specificity of 100 percent. Use of the Optacon to distinguish toxic polyneuropathy from entrapment neuropathy is discussed. The author concludes that this tool allows detection and serial quantification of sensory abnormalities in the workplace, allowing for measurement of deterioration or improvement, and recommends that studies of possible confounding factors be performed.

6. Castelli W, Evans G, Diaz-Perez R, Armstrong T [1980]. **Intraneural connective tissue proliferation on the median nerve in the carpal tunnel.** *Archives of Physical Medicine and Rehabilitation* 61(9):418-422.
GRANT NO: R01OH00679

In order to evaluate the proliferation of the intraneural connective tissue and its intrinsic vasculature, segments were taken from the median nerve from the distal fourth of the right forearm and the carpal tunnel area in 23 embalmed human cadavers. The percentage of the cross-sectional area formed by fascicles plus perineuria in the round cross sections of the nerve (proximal to the flexor retinaculum) was significantly greater in both males and females than in the flat cross sections of the nerve within the carpal tunnel. The flattened cross sections of the median nerve obtained from the carpal tunnel exhibited circumscribed laminated masses of fibrous connective tissue. These were identified as Renault bodies and their presence may indicate abnormal intraneural proliferation of connective

tissue as well. The thicker epineurial and perineurial layers of the median nerve within the carpal tunnel probably represent localized areas of subclinical reactive connective tissue hyperplasia. There were no comparable changes in the nerve fascicles of the median nerve proximal to the carpal tunnel. Remarkable proliferation of the intraneural connective tissue was noted in the flattened sections of most nerves.

7. Emurian H [1991]. **Stress effects of human-computer interactions, final report.** GRANT NO: R01OH02614. 58 pp.
NTIS NO: PB92-136001 PRICE: Check NTIS

Experiments were carried out to investigate the effects of human/computer interactions on indicators of stress. Men solved 50 database queries consecutively presented on a video display terminal (VDT). Each query required solution within 45 seconds of its initial presentation to avoid a reduction in potential earnings. A solution required the correct selection of three successive hypertext indices hierarchically structured from the query to the data answer. In a second study, 16 men and 16 women solved 80 database queries under conditions of high or low work density. The results indicated that motivated time-pressured work at a VDT will produce tonic elevations over a resting baseline in blood pressure, heart rate, and masseter electromyogram (EMG) activity in men and women who are experienced computer users. A relationship exists between the personality of the computer user and the magnitude of systolic blood pressure. Under conditions of 8 second constant and 8 second variable system response times (SRTs) in men, the constant and variable SRTs did not differentially affect physiological responses. Men and women showed higher systolic blood pressure during high density work than during low density work. Females showed reliably greater masseter EMG activity during high density work than during low density work.

8. Gerr F, Letz R, Landrigan P [1991]. **Upper-extremity musculoskeletal disorders of occupational origin.** *Annual Review of Public Health* 12:543-566.
GRANT NO: K01OH00098

A critical review of the scientific evidence relating occupational factors to musculoskeletal disorders of the upper extremities was presented. Topics included: the background of methodological issues; carpal tunnel syndrome (CTS); tendinitis; hand/arm vibration syndrome (HAVS); cumulative trauma disorder; repetition strain injury; occupational cervicobrachial disorders; overuse syndrome; regional musculoskeletal illness; and epidemiological evidence for work-relatedness. Well defined disorders included CTS, tendinitis, and HAVS. Poorly defined disorders included repetition strain injury and musculoskeletal discomfort among visual display terminal operators. The authors conclude that these well defined soft tissue disorders of the upper extremities are etiologically related to occupational risk factors such as force, repetition, and vibration; but, they state that poorly understood factors may be involved. Tool and job redesign may be required in many situations to minimize risk.

9. Goldstein S, Armstrong T, Chaffin D, Matthews L [1987]. **Analysis of cumulative strain in tendons and tendon sheaths.** *Journal of Biomechanics* 20(1):1-6.
GRANT NOS: T01OH0016107 and R01OH006790451

Tests were carried out to determine the viscoelastic properties of tendons and tendon sheaths under simulated physiological loading conditions, using a newly developed method to measure tendon strain. The study was carried out in 25 frozen flexor digitorum profundus tendons from 12 intact cadaver hands belonging to 4 females and 3 males, aged 55 to 72 years, which were subjected to uniaxial step stress and cyclic loads. The interactions of the tendon, tendon

sheath, and retinacula were determined using newly designed clip strain transducers attached on tendons proximal and distal to an intact carpal tunnel. The assumption was made that total stress consisted of a viscous component and an elastic component, and that during physiological applications, the viscous components were negligible as compared to the elastic components. The results obtained revealed that the elastic and viscous responses of the tendon composite fitted fractional power functions of stress and time, respectively. The significant decrease in strain which was evident from the proximal to the distal segment of the tendon was dependent on deviation of the wrist. Creep strain was related to sex and wrist position. The authors conclude that the results provide evidence that creep strain in collagenous tissues may play an important role in the etiology of cumulative trauma disorders, and they suggest further studies to develop recommendations regarding changes in the use patterns of these tissues.

10. Grigg E [1973]. **A continued study of an arm rest for the Amp-o-lectric wire terminating machine.**
GRANT NO: T01OH00161. 18 pp.
NTIS NO: PB88-236997 PRICE: Check NTIS

A laboratory study was conducted to measure the effectiveness of an arm rest, and actual factory tests were conducted on the same arm rest for workers using the Amp-o-lectric wire terminating machine. An evaluation was also made of the interaction of the arm rest with the machine guard. Depth, height, angle, and rotation of the arm rest could be adjusted by the machine operator. In the laboratory study data were collected for 15 gauge wire at 25 wire intervals with about 250 wires being terminated at each setting. Tests were conducted with the arm rest and guard, or with the arm rest without the guard. In other tests the arm rest was set at three different angles: left to right 10 degree downward slant, horizontal, or left to right 10 degree upward slant. The best arm rest angle was the left to right upward slant. Using this angle as a 100 percent productivity reading,

the left to right downward angle afforded an 88.3 percent productivity level and the horizontal rest indicated a production of 96.1 percent. A higher productivity rate was achieved using an arm rest with no guard. In the factory study, data were collected with 20 gauge wire in 50 wire cycles for a total of 400 wires terminated. The author concludes that productivity can be increased by the use of an arm rest, and operator comfort is enhanced.

11. Marras W, Schoenmarklin R [1991]. **Quantification of wrist motion in highly repetitive, hand-intensive industrial jobs, final report.**

GRANT NO: R01OH02621. 136 pp.
NTIS NO: PB91-226191 PRICE: Check NTIS

A study was conducted to investigate the effects of wrist motion components on risk of hand/wrist cumulative trauma disorders (CTDs) in an industrial environment. A quantitative surveillance study was performed in industry in which workers' wrist motion was monitored on the factory floor. A total of 40 subjects from 8 industrial sites participated in the study. The wrist motion parameters that were monitored on each subject were static (position), and dynamic (velocity and acceleration measures in each plane of movement radial/ulnar, flexion/extension, and pronation/supination). The major findings of the study were that wrist position parameters were limited in predicting CTD risk; that there were significant differences between CTD risk levels for all angular velocity and acceleration parameters in all three planes of wrist movement; that the best predictor of CTD risk was flexion/extension average acceleration; that the second best predictor of CTD risk was flexion/extension average velocity; and that there is a need for further research on the dynamic components of wrist motion in order to effectively use quantitative measures of wrist motion to prevent CTDs in industry.

12. Radwin R, Lin M [1993]. **An analytical method for characterizing repetitive motion and postural stress using spectral analysis.** *Ergonomics* 36(4):379-389.
GRANT NO: K01OH00107

The ability of spectral analysis of electrogoniometric data to characterize repetitive wrist motions and postural stress in cyclical tasks was examined. Subjects instrumented with electrogoniometers attached to the dorsum of the wrist of the dominant arm performed a simple peg transfer task utilizing two peg boards. The wrist posture was controlled and forced into a neutral position by adjusting the pegboard locations and having the subjects reach over a horizontal bar placed in front of the upper peg board. The work pace was controlled by an auditory signal from an electronic timer. Wrist flexion or extension angles and ulnar or radial deviations of the wrist from the neutral posture were recorded by the electrogoniometer using a 60 hertz sampling rate. Power spectra were computed from the data by decomposing each task into appropriate segments which were divided by the task elements, defined as a set of movements contained between two arbitrary, distinct breakpoints for each task, utilizing a Fourier transform technique. Attempts were made to correlate the direct current (DC) and alternating current (AC) components of the spectra with wrist posture and joint displacement amplitudes and frequency rates. The DC components were directly related to the sustained wrist postures independently of the AC components. The AC components were significantly associated with displacement amplitudes and repetition rates independently of the DC components. The authors conclude that power spectrum DC components can measure sustained postures and AC components repetitive movements independently of each other. Power spectral analysis can be used for analyzing repetitive motions in cyclic tasks and their relationship to cumulative trauma disorders.

13. Richardson W, Marcus B [1992].
**Prevention of cumulative trauma disorders,
final report.**
GRANT NO: R43OH02907. 96 pp.
NTIS NO: PB93-188332 PRICE: Check NTIS

The use of the GripMaster (GM) to measure the forces involved in hand functions performed on the job was investigated. The GM was designed to measure flexion/extension and radial/ulnar deviation of the wrist plus up to five finger and hand forces. In laboratory experiments the GM's force measurements were compared to a hand dynamometer and electromyograph measurement techniques; measurements of static wrist postures with the GM were compared to video analysis techniques. Force sensor reliability was tested. The GM was field tested at a lock manufacturing facility. While the GM tested in this study demonstrated a high degree of correlation with the more established techniques under certain circumstances, the calibration techniques and the ranges of force and motion measured were shown to be inadequate. The authors conclude that by extending the sensor range, improving the calibration techniques, and making the force sensing technology more robust, the GM can be a valuable tool in assessing and quantifying cumulative trauma disorder risks.

14. Rolecki J [1978]. **Biomechanical analysis
of personal CTS attributes.**
GRANT NO: T01OH00161. 70 pp.
NTIS NO: PB88-247705 PRICE: Check NTIS

The importance of wrist size and the effect of high force loads on tendons were investigated in relation to carpal tunnel syndrome (CTS). The geometry of the curvature of the finger flexor tendons as they pass over the trochlea of the wrist was estimated using a relationship between the change in joint angle of the wrist and displacement of the flexor tendon to determine the radius of curvature of the tendon. Human cadaver limbs were dissected and direct measurement were made of the spatial location of the tendon. The radius of curvature of the tendon in the vicinity of the

trochlea was determined by fitting polynomials to the data. The radius of curvature of the finger flexor tendons was found to range from about 0.9 to 4.0 centimeters. The radius of curvature was larger during flexion than extension. Higher force loadings on the tendon during extension and flexion of the wrist joint may be implied by a smaller radius of curvature. No predisposition of the wrist to the development of CTS was evidenced by the five bone dimensions which indicate wrist size and hand length. Intra wrist forces on the tendon increased significantly as joint thickness decreased during wrist flexion, but not during extension. Variations in wrist structure were not found to be an etiological factor in the occurrence of CTS. The authors recommend that further cadaver study be done to determine whether the values for radius of curvature can be replicated.

5. CONTRACT REPORTS are generated primarily from a contractual agreement between NIOSH and a non-governmental organization. They typically describe scientific research conducted by that organization for NIOSH. Contract reports, which are listed below in alphabetical order by author, may be published either as final reports available from NTIS or as journal articles. For journal articles, bibliographic information is provided to permit retrieval from public or university libraries.

1. Armstrong T, Fine L, Goldstein S, Lifshitz Y, Silverstein B [1987]. **Ergonomics considerations in hand and wrist tendinitis.** *Journal of Hand Surgery* 12A(5)Part 2:830-837. CONTRACT NO: 200-82-2507

In a cross-sectional study, undertaken to evaluate the relationship between repetitiveness, forcefulness, and selected cumulative trauma disorders of the hand and wrist, a total of 652 workers were studied for de Quervain's disease, trigger finger, tendinitis, and tenosynovitis. Workers were selected from jobs with four combinations of force and repetitiveness in seven types of work (electronics, sewing, appliance, bearing fabrication, bearing assembly, and investment molding). Jobs with a cycle time less than 30 seconds or which involved performing the same motion for over 50 percent of the cycle time were classified as high repetitive (HR); low repetitive (LR) jobs had cycle times over 30 seconds and involved performing the same motion less than 50 percent of the cycle time. Jobs with estimated average hand force requirements over 40 newtons were considered high force (HF); jobs with estimated average hand force requirements below 10 newtons were considered low force (LF). Standardized interviews and noninvasive physical examinations were conducted for the subjects. Forty-five workers fulfilled the criteria for tendinitis in the interview, and 29 workers with hand/wrist tendinitis were identified by physical examination and the interview. Prevalence of

hand/wrist tendinitis by force and repetitiveness ranged from 0.6 percent in the LF/LR jobs to 10.8 percent in the HF/HR jobs. Overall prevalence was significantly higher in females (7.8 percent) than in males (1.7 percent). Significant differences in posture between males and females were observed. The authors conclude that there is a highly significant association between recognized signs and symptoms of hand/wrist tendinitis and repetitiveness and forcefulness of manual work.

2. Armstrong T, Fine L, Silverstein B [1985]. **Occupational risk factors. Cumulative trauma disorders of the hand and wrist, final report.** CONTRACT NO: 200-82-2507. 216 pp. NTIS NO: PB87-164380 PRICE: Check NTIS

Possible associations were sought between cumulative trauma disorders and jobs which require highly repetitive or highly forceful hand and wrist motions, irrespective of other factors. Efforts were made to develop field instruments to identify occupationally related upper extremity cumulative trauma disorders (CTDs) in active workers; to estimate the prevalence of upper extremity CTDs among workers in jobs needing force and repetitiveness; to estimate individual and multiplicative contributions of occupational and nonoccupational factors which may be associated with these disorders; and to test the null hypothesis of no association between the prevalence of CTDs among workers with different force and repetitive work requirements. The overall prevalence of upper extremity CTDs estimated in this study was high, 31 percent on interview and 18 percent on physical examination and interview. The prevalence of hand/wrist disorders was 20 percent on interview and 10 percent on physical exam and interview. Hand/wrist CTD prevalence was not uniform across all exposure categories. Hand/wrist CTDs were strongly associated with high force/high repetitive work and to a lesser extent with high repetitiveness or high force alone. According to the authors, irrespective of the type of industry or product, jobs with similar force and repetitiveness

attributes would have similar risks for CTD. The findings suggest that primary prevention can be accomplished through job modification and reductions in force, and repetitive and postural stresses.

3. Armstrong T, Foulke J, Goldstein S, Joseph B [1981]. **Analysis of cumulative trauma disorders and work methods.** PURCHASE ORDER NOS: 80-2891, 80-3647. 145 pp. NTIS NO: PB84-181577 PRICE: Check NTIS

The incidence of cumulative trauma disorders of the upper extremity among workers in a poultry processing facility (SIC-5144) and a furniture panel manufacturing factory (SIC-2511) were investigated. Accident and personnel records were reviewed to determine the number and type of repetitive trauma complaints, such as strain and tendonitis, for each job class. Incidence rates were calculated. Jobs with high incidence rates were selected for work methods analyses to identify stressful postures. Five job types with incidence rates of 17.4 to 129.6 cases per 200,000 work hours in the poultry facility and two jobs having incidence rates of 10.9 and 15.0 cases per 200,000 work hours in the panel factory were studied with films and surface electromyography. Stressful motions and postures were identified from the films. Conclusions and recommendations include modifying tool handles so the tool can be held without deviating the wrist, and relocating work surfaces so they can be reached without twisting the wrist. It is further recommended that these suggestions either be tested in laboratories or by on site pilot studies before they are implemented on a large scale.

4. Keyserling W, Donoghue J, Punnett L, Miller A [1982]. **Repetitive trauma disorders in the garment industry.** PURCHASE ORDER NO: 81-3220. 69 pp. NTIS NO: PB89-215867 PRICE: Check NTIS

The prevalence of repetitive trauma disorders among workers in the garment industry was investigated with the intention of identifying specific sources of ergonomic stress which could be causing these conditions. The prevalence of pain in selected joints and limbs was investigated through a survey of 397 workers, of whom about 25 percent suffered persistent musculoskeletal pain in at least one part of their body. The most frequent location of the pain was the hand, followed by the back and neck. The following tests were also administered: Phalen's Test used to diagnose carpal tunnel syndrome; Tinel's Test used to diagnose carpal tunnel syndrome; Finklestein's Test used to diagnose DeQuervain's disease; and Thumb Rotation Test used to diagnose degenerative joint disease. Particularly high rates of strain were noted among stitchers. The authors recommend that: efforts be made to reduce the coefficient of friction between the fabric being sewn and the working surface of the machines; sewing surfaces of the machines should be slanted in order to possibly reduce the tendency to lean forward; and workers should be rotated among different stitching jobs to reduce the amount of exposure each has to the more strenuous of the tasks.

5. Nelson N, Park R, Silverstein M, Mirer F [1992]. **Cumulative trauma disorders of the hand and wrist in the auto industry.** American Journal of Public Health 82(11):1550-1552. CONTRACT NO: 200-82-2860

The incidence of cumulative trauma disorders of the hand and wrist among workers in automotive factories was studied. Data on the incidence of

carpal tunnel syndrome, DeQuervain's disease, Raynauds's phenomenon, ganglion of the wrist, and ulnar nerve entrapment were obtained. Sources included assembly, trim, foundry, axle, and stamping automotive factories from OSHA Form 200 injury and illness logs from 1984 to 1987 and from medical insurance claims filed over the same period. Cases of cumulative trauma disorders were identified in 59 workers using OSHA logs and in 150 workers using insurance data from all factories combined. The rates of hand and wrist disorders were higher in the assembly and foundry factories compared with the other factories using OSHA records, and highest in axle and foundry factories using insurance data. The largest number of cases were identified in the assembly factory, and within this factory, paint related and trim/chassis areas had the highest rate of cumulative trauma disorders. The authors conclude that medical insurance records identify more cases of cumulative trauma disorders than does the OSHA 200 log.

6. Park R, Nelson N, Silverstein M, Mirer F [1992]. **Use of medical insurance claims for surveillance of occupational disease. An analysis of cumulative trauma in the auto industry.** *Journal of Occupational Medicine* 34(7):731-737.
CONTRACT NO: 200-85-2860

Case/control studies were conducted of cumulative trauma disorders (CTD) occurring among workers who were members of the United Auto Workers (UAW) Union. Medical insurance claims were linked with work histories for workers employed at five different facilities. In these 5 locations there were 11,577 CTD claims for 3,204 workers. The incidence rate from 1985 through 1987 was 105 per 1000 person years in these 5 sites. The incidence was highest for the stamping facility, following by the trim, assembly and the axle divisions. The foundry rate was much lower. A comparison of cases and comparisons revealed a higher proportion of carpal tunnel syndrome (CTS) cases to be women, and rotator cuff syndrome cases were more often found among the

older workers. Sizable interdepartmental differences were noted which were roughly consistent with the crude incidence rate ratios. The pattern of insurance claims noted for CTD indicated that facility medical departments were not functioning effectively as a first line of defense in the detection, prevention, and treatment of cumulative trauma problems.

7. Salvendy G, Smith M, eds. [1981]. **Machine pacing and occupational stress. Proceedings of the International Conference, Purdue University.** London, England: Taylor and Francis Ltd., 384 pp.
CONTRACT NO: 210-80-0002

The proceedings of the International Conference on Machine Pacing and Occupational Stress held in March 1981 are reported. Major topics considered at the conference including perspectives on work pacing and stress, models of human stress, variables related to and the measurement of stress, issues in machine paced research, impact of machine paced work on stress, impact of computer paced work on stress, and problems in determining the relationship between production work and stress are examined.

8. Silverstein B, Fine L, Armstrong T [1987]. **Occupational factors and carpal tunnel syndrome.** *American Journal of Industrial Medicine* 11(3):343-358.
CONTRACT NO: 200-82-2507

A cross-sectional investigation was performed to determine if forceful and repetitive job attributes were positively associated with symptoms and physical signs of carpal tunnel syndrome (CTS). The prevalence of CTS was estimated among 652 active workers in 39 jobs from 7 industrial sites whose jobs were categorized according to specific hand force and repetitiveness characteristics: low force/low repetitive (LOF/LOR); high force/low repetitive (HIF/LOR); low force/high repetitive (LOF/HIR); high force/high repetitive (HIF/HIR). Fourteen cases of CTS were identified on physical

examination and interview; these were distributed over 11 of the 39 jobs. On interview the prevalence of CTS varied from 1.3 percent in the LOF/LOR category to 9.6 percent in the HIF/HIR category. On physical examination and interview, prevalence ranged from 0.6 percent in the LOF/LOR category to 5.6 percent in the HIF/HIR category. Logistic regression analysis suggested that CTS was not significantly associated with gender or facility on physical examination and interview. In the HIF/HIR group, the risk of CTS on physical examination and interview was more than 15 times that of the LOF/LOR group. Force seemed to be a less important risk factor than repetitiveness. There was confounding between HIF/HIR and vibration. When postural variables were entered into the logistic regression models, they were not significant predictors. The authors conclude that HIF/HIR and to a lesser extent high repetitiveness alone are strongly associated with CTS.

had temporary job changes due to disorders in the preceding 3 years. Transfer was more frequent for workers with high force and high repetitive jobs. No relationship between ergonomic changes and change in prevalence of chronic hand/wrist disorders was found.

9. Silverstein B, Fine L, Stetson D [1987].
Hand-wrist disorders among investment casting plant workers. *Journal of Hand Surgery* 12A(5) Part 2:838-844.
PURCHASE ORDER NO: 86-71758

A follow-up study of hand/wrist disorders was conducted among investment casting factory workers 3 years after the original 1983 study. Participants were divided into four exposure categories according to hand force requirements and repetitiveness characteristics of their jobs: low force, low repetitive; high force, low repetitive; low force, high repetitive; and high force, high repetitive. The same standardized interview and noninvasive physical examination performed in 1983 were repeated in 1986, and additional questions on job satisfaction were added to the interview. Of the 152 participants in the original study, 136 participated in the follow up; approximately 25 percent had different jobs in 1986. Thirty-five percent of participants who had different jobs in 1986 were transferred because of hand/wrist disorders. Eleven percent of workers who had the same job during both surveys had