CUMULATIVE TRAUMA DISORDERS IN THE WORKPLACE

BIBLIOGRAPHY

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

HOW TO USE THIS PUBLICATION

This publication is divided into two parts. Part I includes complete or partial copies of NIOSH and non-NIOSH references on cumulative trauma disorders (CTDs). These references were selected to provide a summary of NIOSH research and policy, and to provide CTD information of general interest to the reader. The titles of the references in Part I are listed in the Contents (page iii).

Part II contains a comprehensive bibliography of NIOSH documents on cumulative trauma disorders (Part II.A), as well as a brief listing of selected non-NIOSH references (Part II.B). Part II.A is arranged in six sections by type of NIOSH document. A brief description of each document type precedes the listing of documents in that section. Each document citation includes the title and year of publication, the number of pages, and where applicable, identifying number(s) and ordering information (see below). In addition, a brief abstract of each NIOSH document is provided. These abstracts were taken from NIOSHTIC®, a bibliographic database of worldwide occupational safety and health references maintained by NIOSH. (More information about NIOSHTIC® is available by calling the NIOSH 800-number information service at 1-800-356-4674; press 1, and follow the prompts for databases.)

Documents listed in Part II are NOT available from NIOSH. However, they may be obtained as follows:

1. Copies of any document cited with an "NTIS NO" may be ordered from the National Technical Information Service (NTIS) using the NTIS order form on page 209. Both paper and microfiche copies are available. NTIS has recently changed its pricing schedule; current prices should be confirmed with NTIS before ordering (telephone 703-487-4650). ***Do NOT send NTIS orders to NIOSH.***

2. Copies of journal articles and book chapters listed in Part II.A (Sections 3, 4, and 5) and Part II.B may be obtained from a university or public library using the bibliographic information provided in the citation.

NOTE: This publication replaces the NIOSH bibliography *Carpal Tunnel Syndrome Selected References,* March 1989.

CUMULATIVE TRAUMA DISORDERS IN THE WORKPLACE

BIBLIOGRAPHY

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INTRODUCTION

The primary purpose of this publication is to provide a compilation of materials describing research conducted by the National Institute for Occupational Safety and Health (NIOSH) on cumulative trauma disorders (CTDs) in the workplace. Research on CTDs is conducted as part of the Institute's program on work-related musculoskeletal disorders. A description of this program, and a summary of its findings and recommendations, are included in Part I.

NIOSH defines work-related musculoskeletal disorders as those diseases and injuries that affect the musculoskeletal, peripheral nervous, and neurovascular systems that are caused or aggravated by occupational exposure to ergonomic hazards (see Part I, reference C). A definition of CTDs can be constructed by combining the separate meanings of each word. **Cumulative** indicates that these injuries developed gradually over periods of weeks, months, or even years as a result of repeated stresses on a particular body part. The cumulative concept is based on the theory that each repetition of an activity produces some trauma or wear and tear on the tissues and joints of the body. The word **trauma** signifies bodily injury from mechanical stresses. **Disorders** refers to physical ailments or abnormal conditions. The term **CTD** is generally used to describe disorders of the upper extremities (e.g., hands, shoulder, neck). Therefore, references on disorders or injuries of the back or legs have been intentionally omitted from the bibliography in Part II of this publication.

Perhaps the best known occupational cumulative trauma disorder is carpal tunnel syndrome, which is caused by compression of the median nerve within the carpal tunnel of the wrist. A diagram of the wrist showing its internal components appears in Figure 1 (page vi). For additional information specifically on carpal tunnel syndrome, see Part I (reference H) as well as references listed in Part II.

In addition to the references listed in this publication, there are numerous occupational, medical, surgical, and ergonomics journals in which related articles on cumulative trauma disorders are likely to appear on a regular basis. Listed below are some of these journals; however, keep in mind that this list is not exhaustive.

American Journal of Industrial Medicine
Applied Ergonomics
British Journal of Industrial Medicine
Ergonomics
International Journal of Industrial Ergonomics
Journal of Bone and Joint Surgery
Journal of Hand Surgery
Journal of Occupational Medicine
Muscle and Nerve
Neurology
Orthopedics
Rheumatology and Rehabilitation
Scandinavian Journal of Work, Environment and Health

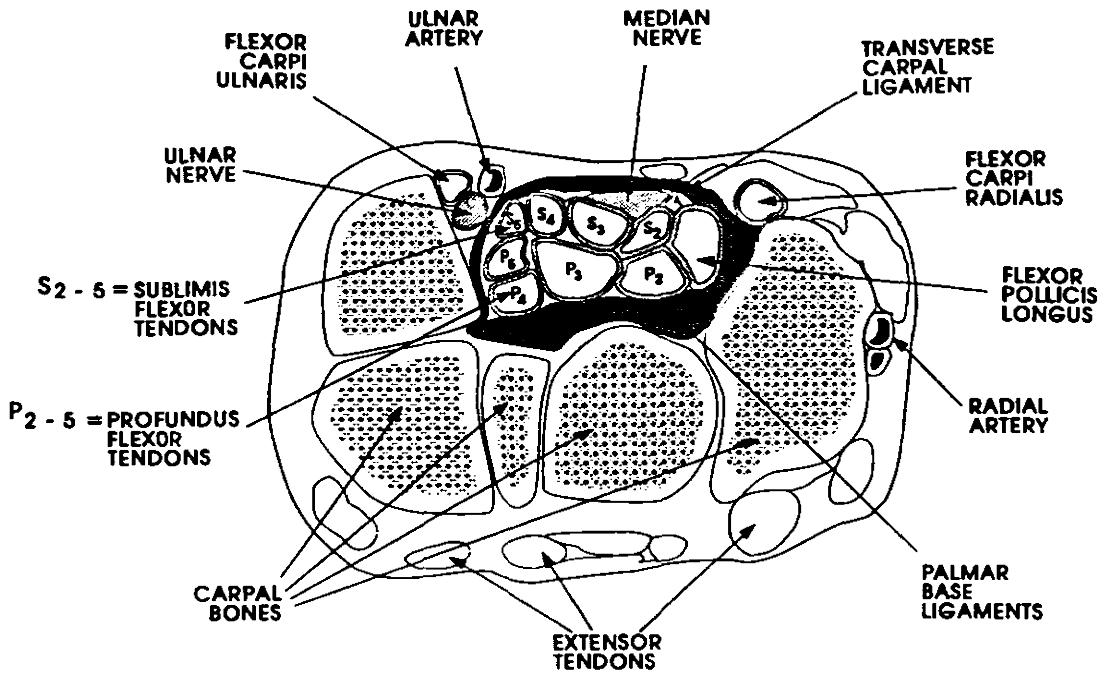

Figure 1. Transverse section of right wrist looking distally (with the palm side up), showing relative positions of the median nerve, flexor tendons, transverse carpal ligament and carpal bones. Note that the shape of the median nerve is conforming to the space available to it inside the tunnel. (From Tanaka S and McGlothlin J [1993]. A conceptual quantitative model for prevention of work-related carpal tunnel syndrome (CTS). International Journal of Industrial Ergonomics *11*(3):181-193.)

PART I

SELECTED NIOSH AND NON-NIOSH REFERENCES ON CUMULATIVE TRAUMA DISORDERS

A. NIOSH ACTIVITIES IN PREVENTING WORK-RELATED MUSCULOSKELETAL DISORDERS

There is widespread recognition that work-related musculoskeletal disorders (WMSDs) are common and increasing in the United States. Between 1982 and 1994, the reported number of musculoskeletal disorders of the upper extremity has steadily increased, accounting in 1990 for more than 60% of all occupational illnesses, the most recent year for which statistics are available (BLS 1994). Studies conducted by NIOSH staff have documented work-related musculoskeletal disorders in a wide range of industries including newspapers, health care, telecommunications, manufacturing of transportation equipment, construction, and food processing. Depending on the job, these disorders may cause pain, restricted motion, and weakness in the hands, arms, shoulders, neck, back, and lower limbs.

In a recent national health interview survey, 1.62 million workers (1.47%) reported symptoms of hand discomfort consistent with carpal tunnel syndrome, one of the most serious disabling conditions that is associated with performing repetitive and forceful manual work (Tanaka et al. 1995). In 1989, meat packing, poultry processing, and motor vehicle manufacturers had the highest reported rates of repeated trauma disorders in the manufacturing sector, based on data from the OSHA 200 logs. Coupled with the human costs in suffering and lost wages, work-related musculoskeletal disorders are responsible for growing economic costs to the nation as evidenced by increases in worker's compensation costs, as well as escalating costs of diagnosis and treatment. Total compensable costs to the nation for these disorders is estimated to exceed $20 billion annually (BLS 1993).

To address this growing problem, NIOSH and the Association of Schools of Public Health convened a Conference more than ten years ago involving 50 expert panelists and 450 other occupational safety and health professionals. The resulting document, released in 1986, summarizes 12 broad tactical approaches, and 23 immediate and future actions needed to understand and prevent a variety of occupational musculoskeletal injuries. This document, entitled Proposed National Strategy for the Prevention of Musculoskeletal Injuries, served as the NIOSH blueprint or strategy for setting research priorities through the end of the decade (NIOSH 1986).

A second Conference was held in early 1991 to examine the progress towards implementation of the recommendations in the 1986 plan. To perform this examination, a one and one-half day Conference and Workshop was held in Ann Arbor, Michigan. The proceedings from the Conference were published in a document entitled A National Strategy for Occupational Musculoskeletal Injury Prevention: Implementation Issues and Research Needs (NIOSH 1992). These two NIOSH Prevention Strategies provide a comprehensive view of the primary components of an effective research program for reducing the frequency and severity of work-related musculoskeletal problems.

Subsequently, employers, employees (with support from organized labor), loss control insurers, academia, states, and the federal sector have joined hands in seeking new ways of preventing and controlling work-related musculoskeletal disorders. In this context, the following general research recommendations were developed by the conference participants (NIOSH 1992).

1. An improved capability to identify hazardous job stressors is needed that recognizes how subtle physical exertions on jobs combine with other risk factors (such as awkward postures, high repetition, long work cycles, cold temperatures, vibrations, or high amounts of psychosocial stress) to create musculoskeletal tissue trauma, pain, and disability.

2. An improved ability to objectively measure and quantify job stresses believed to cause WMSDs is needed. In particular, we must develop more sensitive measurement systems, capable of accurately describing small body motions, and static and dynamic forces now required in many jobs that are known to cause localized tissue trauma and disability.

3. Most participants believed that there is a rapidly growing need to develop objective medical tests to identify people who may be at special risk of WMSDs when exposed to certain job conditions. Such tests need to be carefully constructed to be safe, reliable, accurate, and efficient (low operational time cost); to be directly related to the job requirements; and to be highly predictive of an individual's risk level when required to perform a specific manual task in a job. Other participants were concerned about the feasibility for this type of testing in a prevention program from a policy or scientific perspective.

4. Much more fundamental biomechanical and other types of research is needed to understand why for the majority of the WMSDs the specific nature of the damage to the body cannot be conclusively established during routine clinical evaluations. Worker population biomechanical tolerance data are needed to specific tissue and musculoskeletal structures. In addition, biomechanical models that more accurately predict tissue stress levels during work are needed, as well as empirical studies to validate the output from these models.

5. Job hazard surveillance and health-related reporting systems for WMSDs need to be improved. These should be easily implemented (user-friendly) systems that link job hazard data (from job evaluations, checklists, psychophysical effort reports, and worker questionnaires) to medical injury and illness reports in a timely fashion.

6. A variety of WMSDs control procedures and equipment are available today. These controls need to be carefully evaluated to determine their effectiveness in preventing future WMSDs, and the operational conditions under which they are effective. Additional research is recommended to refine the effectiveness of early comprehensive medical interventions and rehabilitation strategies.

7. The design of various industrial planning and social-organizational issues need to be studied to understand how these impact the implementation of various control strategies.

References

BLS [1993]. Occupational injuries and illnesses in the United States by industry, 1991. Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics, Bulletin 2424.

BLS [1994]. Workplace injuries and illnesses in 1993. Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics, USDL 94-600.

NIOSH [1986]. Proposed national strategy for the prevention of musculoskeletal injuries. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 89-129.

NIOSH [1992]. A national strategy for occupational musculoskeletal injuries: implementation issues and research needs. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 93-101.

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.

Proceedings of the Sixth FIOH-NIOSH Joint
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Work-related musculoskeletal disorders: prevention and intervention research at NIOSH

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Introduction

Work-related musculoskeletal disorders (WMD) have been a recognized problem since the 17th century when Bernardo Ramazzini first described the illnesses caused by "violent and irregular motions and unnatural postures of the body" (1), and cited the strains on the hands and arms of scribes and notaries which led to a "failure of power to the right hand." By the end of the 19th century, the same conditions and symptoms were noted not only in scribes but also in other occupations such as shoemakers, milkmaids and seamstresses (2). In the 20th century, the incidence of cumulative trauma disorders (CTDs) and other WMD began to escalate dramatically – in the United States and in other industrialized countries as well. The costs, both economic and human, are immense. As an example, the rates of reported upper extremity disorders in the United States (US) tripled between 1986 and 1992 (3). This increase is accompanied by lost work days and reduced productivity: Workers suffering from carpal tunnel syndrome were away from work for 32 days (median value). Low back pain is a greater problem: A study of 1989 workers' compensation costs (4) reported that low back disorders represented 16 % of all claims and 33 % of all claims costs with a mean cost of USD 8,300/case.

Clearly, the development and implementation of appropriate preventive strategies for WMDs is of urgent importance. The classic approaches to the resolution of a public health problem start with surveillance; proceed through the conduct and completion of relevant (both laboratory and field) research studies to elucidate the etiology and develop the methods needed to fully characterize the problem; and, finally, design and implement appropriate interventions. Current public health research practice too often emphasizes only the first two steps of this process. Although these steps are necessary to identifying and evaluating the problems, they are not sufficient to ensure effective prevention. A greater research emphasis on the prevention/intervention efforts themselves is needed. However, the development and delivery of prevention technologies are only the first steps in implementing effective prevention programs. Of equal importance is the need to evaluate and demonstrate the effectiveness of these prevention strategies and then to effectively communicate this knowledge to others.

NIOSH is refocussing our research efforts, placing a greater emphasis on prevention/intervention efforts. This report provides examples of current NIOSH research activities directed at the prevention of WMDs. These research studies are collaborative efforts which utilize skills and expertise found in five NIOSH Divisions[1].

Development of prevention strategies: from laboratory to field research

Exposure assessment tools

Traditional ergonomic job analysis techniques have relied on experts to conduct time-consuming task analyses through direct observations or evaluation of photographic/videotaped records. An easy to use "Ergonomic Hazard Identification Checklist" has been developed which can be used by industrial hygienists and other safety personnel for initial ergonomic evaluations of jobs/tasks. The checklist covers 14 different task factors which the investigator observes and rates as "never," "some ($\leq$ 3 times daily)" or "usually (>3 times daily)." Use of this tool can quickly identify potentially hazardous tasks and trigger follow-up ergonomic assessment by an expert.

The usefulness and validity of the checklist is being assessed by comparing the checklist ratings of 50 representative tasks with ergonomists' expert assessment of the same tasks.

In 1981, NIOSH developed and published an equation for calculating a recommended weight limit for specified two-handed, symmetrical lifting tasks. In 1991, the equation was revised using more recently published biomechanical, physiological, psychophysical and epidemiological data to address a more diverse range of lifting tasks (5). The equation allows computation of a recommended weight limit for a lifting task (the ratio of the weight lifted by the worker to the recommended weight limit); and a lifting index. The equation can also be used for job redesign by identifying the most hazardous features of the lifting task. A current study is directed at validation of the equation for predicting risk of a back injury. The initial phase of the validation will include a comparison of exposure data, workers' compensation records and other records of injuries for exposed workers with similar data for unexposed workers. The goal of this study is to provide data defining the relationship between the lifting index and the incidence and severity of work-related low back pain or injury.

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1. Division of Safety and Research, Division of Surveillance, Hazard Evaluations and Field Studies, Division of Physical Sciences and Engineering, Division of Biomedical and Behavioral Science, and Educational and Information Division.

In 1994, NIOSH published a manual (6) which explained the procedures and provided examples for accurately applying the lifting equation to a variety of lifting tasks. Efforts are underway to develop an interactive computer-based training module for applications of the lifting equation.

Evaluation of the efficacy of back belts for prevention of low back injury

Efforts to control or prevent back injuries have included a variety of approaches. Recently, "back belts" have been promoted as a control solution. A variety of employers, from retail store chains to hospitals, have introduced back belts or back supports to the workers; some have instituted mandatory use policies. Numerous inquiries to NIOSH both from management and labor about the effectiveness of back belts in preventing low back injury led to a comprehensive review and evaluation of the published, scientific literature on back belt use (7). From this review, NIOSH concluded that the laboratory and epidemiologic data were insufficient to support the assertion that back belts reduce or prevent low back injury. More research was clearly needed to augment the available scientific data on use of back belts.

Based on these findings, NIOSH is undertaking both laboratory and field studies. In a laboratory study of approximately 100 different industrial-type back belts, investigators are examining physiologic, psychophysical and biomechanical aspects related to the use of the belts. Factors included in the evaluation are spinal load reduction, heat retention and fatigue, changes in range of motion and resonance frequency alterations after exposure to whole body vibration. To examine the efficacy of back belts in the reduction of the workplace incidence of low back injury, NIOSH also will conduct a 24-month prospective study of approximately 8,000 employees of a large retail company which 2 years ago instituted a company-wide mandatory back belt program. workers will be divided into three groups: back belts worn for only 12 months of the study period, and worn (or not worn) throughout the study period. Self-administered medical histories will document low back symptoms and compensation data from company files will document injuries which lead to lost work days. Exposure to lifting tasks will be characterized andrecorded periodically by NIOSH investigators. The goals for these two studies are to provide data not only on the effects of back belt use but also of their effectiveness in preventing low back injury.

Delivery of prevention technologies: evaluating intervention efforts

HETA follow-ups

NIOSH provides technical assistance to employers, workers, and regulatory agencies through a Hazard Evaluation and Technical Assistance (HETA) program. An increasing number of requests for assistance in recent years have been related to ergonomics and work-related musculoskeletal disorders. To evaluate the efficacy of NIOSH assistance related to ergonomics, follow-up contacts were made with companies where NIOSH had provided significant ergonomic recommendations during the previous 10 years. The effects of changes made by 7 companies (a large metropolitan newspaper publisher, a supermarket chain, two printing companies, a plastics manufacturing facility, an appliance glass manufacturing facility, and a motorcycle manufacturing facility) were evaluated. In all of the facilities, some attempts had been made to address ergonomic problems.

Although it is difficult to separate out the contributions of the many different concurrent changes such as downsizing, product changes and safety and health policy changes, attempts to redesign the workplaces contributed to some successes in reducing the number and severity of musculoskeletal problems. Also, some important lessons about what facilitated or impeded the success of an intervention program were learned. The most successful programs were those that included a comprehensive approach to the problem and utilized active input from front-line workers in the planning and implementation of changes.

Efforts at a major motorcycle manufacturing company exemplified a successful approach towards developing an ergonomic intervention program(8). In 1990, NIOSH received a joint labor/management request for assistance in evaluating musculoskeletal problems. Of particular concern was the flywheel milling department in which there had been a dramatic increase in the number of injuries and lost work days. One of the key tasks in this department was the process used to straighten or "true" the flywheel. This job, in which a brass-head hammer is used to deliver a forceful blow, required tremendous skill. However, between 1982 and 1990, ten workers had been injured doing this job and there were few skilled workers left who could perform this task. In 1989, 27 % of the workers in the department had developed a musculoskeletal disorder requiring either work restriction or time off the job. NIOSH conducted an in-depth ergonomic evaluation and worked with this company to develop and evaluate changes in the truing task as well as in several other work processes in the factory. The change in the truing process was probably the most dramatic. A new press was acquired which completely eliminated the use of brass hammers and thus of manual force. While the new press cost USD 51,000, the cost of the brass hammers had been USD 40,000 per year. Thus, even if the cost of the injuries are not included, this intervention completely paid for itself in less than 2 years. More importantly, the postintervention incidence rate for recorded musculoskeletal disorders in this department showed a 29 % decrease while the severity rate, as measured by restricted or lost workdays, decreased by 82 %. Other changes were also implemented in the factory. Some of the changes, such as raising the drill press to avoid stooped working postures, cost little. Additionally, some of the changes not only reduced exposure, but increased production quantity and quality. It is estimated that these changes saved the company over USD 50,000/year in costs related to musculoskeletal problems.

The approach this company took exemplifies some of the principles which we found were most likely to lead to a successful intervention program: 1) The company involved the workers in every step. An intervention team was formed that consisted of production workers, supervisors and engineers. 2) The management gave full support to this team, allowing them to make decisions and facilitated a quick turn around time for purchasing new equipment. 3) The team developed the concept for the new equipment and worked with the equipment manufacturers to assure that it was designed correctly. 4) After the new equipment was installed , there was a transition period during which workers could evaluate and make final adjustments to the new equipment.

Meatpacking industry

Ergonomic hazards in the US meatpacking (slaughtering, processing and packaging) industry are legendary in the US. In the late 1980s, the meatpacking industry's incidence of disorders due to "repeated trauma" was approximately 75 times that of industry as a whole. Demonstration studies at three different places were undertaken to examine the utility of participatory approaches in addressing ergonomic problem areas (9). The efforts were aided by university investigators with expertise in ergonomics (and, in one case, organizational behavior) who collaborated with and provided guidance to the teams. The teams included production workers, supervisors, as well as staff from other departments; the goals were to identify and solve ergonomic problems and reduce musculoskeletal injuries.

In each of the case studies, benefits from this type of participatory intervention approach were recorded. While each of the intervention approaches measured benefits somewhat differently, there were successes in reducing incidence rates of cumulative trauma disorders, lost work days and compensation costs. In addition, these intervention efforts were instrumental in fostering an increased knowledge about the use of participation of workers and others in developing work site improvements and problem-solving efforts.

Office environment: work organization issues

The increased prevalence of WMDs associated with video display terminal (VDT) work has been well documented. Characteristics of data entry tasks frequently include constrained postures, highly repetitive movements of the fingers, hands, and wrists and static muscle loading. These working conditions can produce musculoskeletal strain and discomfort as well as other deleterious effects. Intervention efforts have usually focussed solely on ergonomically optimizing the work environment. However, these efforts have been less than fully effective in eliminating operator discomfort and performance decrements.

Therefore, NIOSH initiated a series of laboratory studies to examine the effects of changes in work organization factors such as rest break regimens. These studies have evaluated a variety of changes such as number and length of breaks, as well as active (i.e., involving physical exercise) vs. passive rest breaks. The results showed that conventional rest break schedules (mid-morning and mid-afternoon breaks of 10–15 minutes) may not be optimal for highly repetitive VDT work. There were significant performance (up to 15 %) and comfort gains with more frequent, shorter rest breaks; in contrast, the benefits were modest, if any, from including exercises in the rest break regimen. The results also showed that for work periods with infrequent breaks, there was a higher prevalence of poor, potentially hazardous work postures (10,11,12). However, the alternate rest break regimens did not completely eliminate the decrements in overall productivity and operator comfort over the workday which have been observed in all of the laboratory studies of VDT work conventional rest breaks regimens. Additional intervention strategies such as job redesign/task rotation may be needed for these aspects.

A field replication and validation of these laboratory studies is currently underway. The effects of an alternate rest break schedule on comfort and performance have been evaluated in a pilot study of 100 data entry operators at a large service center; a second, similar pilot study is underway. The results obtained to date confirm the findings of the laboratory studies. A large scale prospective validation study of rest break regimens and tests of various job redesign strategies such as job enlargement, task rotation, etc. for workers engaged in intensive data processing tasks will be initiated late in 1995. Data on worker performance, objective performance measures and measures of musculoskeletal strain will be collected and related to the development of musculoskeletal problems in this workforce.

Summary

Documentation of these and other success stories are essential to the continued development and implementation of effective intervention strategies. While we have made a start in these efforts, we still have a long road ahead of us in the prevention of the tens of thousands of cases of musculoskeletal disorders and injuries which occur each year. Implementation of interdisciplinary approaches – which incorporate knowledge about the causes of musculoskeletal disorders, engineering changes in the work environment and the insights of social science about organizational and individual behavior – is an essential basis for these efforts. But to effectively move from research to the practice of prevention, we need to move beyond the traditional uni-directional approaches (surveillance followed by etiological research and experimental intervention efforts) by implementing approaches which are interdisciplinary, dynamic and interactive. Implementation of specific prevention strategies needs to be undertaken even when we still lack definitive knowledge about some aspects of the strategy and cannot assure in advance that a given strategy is the best and final approach to effective prevention. This interactive approach, with on-going evaluation and adjustment of the prevention efforts, will enable us to more quickly eliminate, or at the least minimize, the tremendous toll of work-related musculoskeletal injuries and disorders.

References

1. Ramazzini B. *De Morbis Artificum* Diatriba 1717. In: Wright W(trans): The Disease of Workers. 1940. University of Chicago Press, Chicago.
2. Pfeffer GB, et al. The History of Carpal Tunnel Syndrome. The Journal of Hand Surgery, 1988;13B:29–34.
3. US Department of Labor, Bureau of Labor Statistics. Occupational Injuries and Illnesses by Injury, 1992. Washington, DC. US Government Printing Office, 1993.
4. Webster BS, Snook SH. The cost of 1989 workers' compensation low back pain claims. Spine, 1994(10):1111–5.
5. Waters TR, Putz-Anderson V, Gary A, and Fine LJ. Ergonomics, 1993,749–76.
6. Waters TR, Putz-Anderson V, Gary A. Revised Lifting Equation, DHHS (NIOSH) Publication #94–110, June 1994.
7. Workplace Use of Back Belts, DHHS (NIOSH) Publication #94–122, July 1994.
8. McGlothlin J, Baron, S. Health hazard evaluation: Harley Davidson, Inc., Milwaukee, Wisconsin. HETA #91–0208–2242. National Institute for Occupational Safety and Health, Cincinnati, Ohio.
9. Gjessing C, Schoenborn TC, Cohen A, eds. Participatory Ergonomic Interventions in Meatpacking Plants. 1994. DHHS(NIOSH) Publication #94–124.
10. Swanson NG and Sauter SL. The relationships of working posture to performance in a data entry task. In: MJ Smith and G Salvendy, eds. Interaction: Applications and Case Studies, New York. Elsevier, 1993, 994–8.
11. Swanson NG and Sauter SL. The effects of exercise on the well-being and performance of data entry operators. In: H Lucznak, A. Cakir and G. Cakir, eds. Work with Display Units '92, Elsevier Science Publishers B.V.1993,288–91.
12. Sauter SL and Swanson NG. The effects of increased rest breaks on the health and performance of data entry operators. Presented at the Work with Display Units '92, Berlin, Germany, September 1992.

**COMMENTS FROM THE
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
ON
THE OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION
PROPOSED RULE ON
ERGONOMIC SAFETY AND HEALTH MANAGEMENT**

**29 CFR Part 1910
Docket No. S-777**

**U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health**

February 1, 1993 and August 24, 1993

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NIOSH COMMENTS

The National Institute for Occupational Safety and Health (NIOSH) supports the initiation of rulemaking on ergonomic safety and health management by the Occupational Safety and Health Administration (OSHA). NIOSH recognizes that "ergonomics" is a wide-ranging term with various applications. NIOSH has limited its comments to ergonomic hazards that relate to musculoskeletal problems. The standard should apply to all industries under OSHA jurisdiction, including general industry, agriculture, maritime, and construction.

As OSHA states in its advance notice of proposed rulemaking (ANPR), there is a significant increase in reported cases of ergonomic disorders in the workplace. The ANPR references substantial surveillance data indicatin/g that work-related musculoskeletal disorders are a priority problem for U.S. industry. The importance of work-related musculoskeletal disorders is also reflected in NIOSH experience through its health hazard evaluation program and industrywide studies. NIOSH is conducting ergonomic research and responding to ergonomic concerns of employers and workers across the entire range of U.S. industries and a myriad of occupations, work tasks and operations.

NIOSH offers the following comments to assist OSHA in its development of a proposed rule on ergonomics.

I. INTRODUCTION

A. Definition of "Ergonomic Hazards" and "Ergonomic Disorders"

NIOSH Recommended Revised "Definition of Ergonomic Hazards":

Ergonomic hazards relative to work-related musculoskeletal disorders refer to physical stressors and workplace conditions that pose a risk of injury or illness to the musculoskeletal system of the worker. Ergonomic hazards include repetitive and forceful motions, vibration, temperature extremes, and awkward postures that arise from: improperly designed workstations, tools, and equipment; and improper work methods. The effects of ergonomic hazards may be amplified by extreme environmental conditions. In addition, ergonomic hazards may arise from potentially deleterious job designs and organizational factors such as: excessive work rates; external (versus self) pacing of work; excessive work durations; shiftwork; imbalanced work-to-rest ratios; demanding incentive-pay or work standards; restriction of operator body movement and confinement of the worker to a work station without adequate relief periods; electronic monitoring; and lack of task variety.

NIOSH Recommended Revised "Definition of Ergonomic Disorders":

NIOSH recommends that the term "ergonomic disorders" be replaced with the term "work-related musculoskeletal disorders" to be consistent with the NIOSH recommendation for scope of this standard. Work-related musculoskeletal disorders are those diseases and injuries affecting the musculoskeletal, peripheral nervous, and neurovascular systems that are caused or aggravated by occupational exposure to ergonomic hazards. These disorders are variously referred to as "chronic trauma disorders," "repetitive strain injuries," "repetitive motion injuries," "repetitive trauma disorders," "cumulative trauma disorders," "wear and tear disorders," "overuse syndrome," and "degenerative joint diseases."

Work-related musculoskeletal disorders include damage to tendons, tendon sheaths, synovial lubrication of the tendon sheath, bones, muscles, nerves and ligaments of the hands, wrists, elbows, shoulders, neck, back, hips, knees, and ankles; joint injuries in which some of the fibers of a supporting ligament are ruptured, but the continuity of the ligament remains intact; overstretching or overexertion of some part of the musculature; and a variety of disorders marked by inflammation, degeneration, or metabolic derangement of the connective tissue structures of the body, especially the joints and related structures, including muscles, bursae, tendons and fibrous tissue.

The following diseases in the International Classification of Diseases (ICD) can be caused or aggravated by occupational exposure to ergonomic hazards. However, disorders such as carpal tunnel syndrome can also be caused or aggravated by nonoccupational factors such as carpal tunnel syndrome [Franklin et al. 1991].

ICD Code	Description of Disorder
353	Nerve root and plexus disorders
353.2	Cervical root lesions, not elsewhere classified
353.3	Thoracic root lesions, not elsewhere classified
353.4	Lumbosacral root lesions, not elsewhere classified
354	Mononeuritis of upper limb and mononeuritis multiplex
354.0	Carpal tunnel syndrome
354.1	Other lesion of median nerve
354.2	Lesion of ulnar nerve
354.3	Lesion of radial nerve
355	Mononeuritis of lower limb
355.1	Meralgia paresthetica
355.2	Other lesion of femoral nerve
355.3	Lesion of lateral popliteal nerve
355.5	Tarsal tunnel syndrome
355.7	Other mononeuritis of lower limb
443.0	Raynaud's syndrome (due to vibration)

712	Crystal arthropathies
715	Osteoarthrosis and allied disorders
716.1	Traumatic arthropathy
716.9	Arthropathy, unspecified
719	Other and unspecified disorders of joint
719.0	Effusion of joint
719.4	Pain in joint
719.5	Stiffness of joint, not elsewhere classified
719.7	Difficulty in walking
719.8	Other specified disorders of joint
720.2	Sacroiliitis, not elsewhere classified
722	Intervertebral disc disorders
722.0	Displacement of cervical intervertebral disc without myelopathy
722.1	Displacement of thoracic or lumbar intervertebral disc without myelopathy
722.2	Displacement of intervertebral disc, site unspecified, without myelopathy
722.3	Schmorl's nodes
722.4	Degeneration of cervical intervertebral disc
722.5	Degeneration of thoracic or lumbar intervertebral disc
722.6	Degeneration of intervertebral disc, site unspecified
722.7	Intervertebral disc disorder with myelopathy
722.9	Other and unspecified disc disorder
723.1	Cervicalgia
723.3	Cervicobrachial syndrome (diffuse)
723.4	Brachial neuritis of radiculitis NOS
723.9	Unspecified musculoskeletal disorders and symptoms referable to neck
724.1	Pain in thoracic spine
724.2	Lumbago
724.3	Sciatica
724.4	Thoracic or lumbosacral neuritis or radiculitis, unspecified
724.7	Disorders of coccyx
724.9	Other unspecified back disorders
726	Peripheral enthesopathies and allied syndromes
726.0	Adhesive capsulitis of shoulder
726.1	Rotator cuff syndrome of shoulder and allied disorders

726.10	Disorders of bursae and tendons in shoulder region, unspecified
726.11	Calcifying tendinitis of shoulder
726.12	Bicipital tenosynovitis
726.19	Other specified disorders
726.2	Other affections of shoulder region, not elsewhere classified
726.3	Enthesopathy of elbow region
726.30	Enthesopathy of elbow, unspecified
726.31	Medial epicondylitis
726.32	Lateral epicondylitis
726.33	Olecranon bursitis
726.39	Other
726.4	Enthesopathy of wrist and carpus
726.5	Enthesopathy of hip region
726.6	Enthesopathy of knee
726.60	Enthesopathy of knee, unspecified
726.61	Pes anserinus tendinitis or bursitis
726.62	Tibial collateral ligament bursitis
726.63	Fibular collateral ligament bursitis
726.64	Patellar tendinitis
726.65	Prepatellar bursitis
726.69	Other
726.7	Enthesopathy of ankle and tarsus
726.70	Enthesopathy of ankle and tarsus, unspecified
726.71	Achilles bursitis or tendinitis
726.72	Tibialis tendinitis
726.73	Calcaneal spur
726.79	Other
726.8	Other peripheral enthesopathies
726.9	Unspecified enthesopathy
726.90	Enthesopathy of unspecified site
726.91	Exostosis of unspecified site
727	Other disorders of synovium, tendon, and bursa
727.0	Synovitis and tenosynovitis
727.03	Trigger finger (acquired)
727.04	Radial styloid tenosynovitis
727.2	Specific bursitides often of occupational origin
727.4	Ganglion and cyst of synovium, tendon, and bursa
727.8	Other disorders of synovium, tendon, and bursa
727.9	Unspecified disorder of synovium, tendon, and bursa
728	Disorders of muscle, ligament, and fascia
729	Other disorders of soft tissues
729.1	Myalgia and myositis, unspecified
729.2	Neuralgia, neuritis, and radiculitis, unspecified

729.5	Pain in limb
729.8	Other musculoskeletal symptoms referable to limbs
840	Sprains and strains of shoulder and upper arm
840.0	Acromioclavicular (joint) (ligament)
840.1	Coracoclavicular (ligament)
840.2	Coracohumeral (ligament)
840.3	Infraspinatus (muscle) (tendon)
840.4	Rotator cuff (capsule)
840.5	Subscapularis (muscle)
840.6	Supraspinatus (muscle) (tendon)
840.8	Other specified sites of shoulder and upper arm
840.9	Unspecified site of shoulder and upper arm
841	Sprains and strains of elbow and forearm
841.0	Radial collateral ligament
841.1	Ulnar collateral ligament
841.2	Radiohumeral (joint)
841.3	Ulnohumeral (joint)
841.8	Other specified sites of elbow and forearm
841.9	Unspecified site of elbow and forearm
842	Sprains and strains of wrists and hand
842.0	Wrist
842.00	Unspecified site
842.01	Carpal (joint)
842.02	Radiocarpal (joint) (ligament)
842.09	Other
842.1	Hand
842.10	Unspecified site
842.11	Carpometacarpal (joint)
842.12	Metacarpophalangeal (joint)
842.13	Interphalangeal (joint)
842.19	Other
843	Sprains and strains of hip and thigh
843.0	Iliofemoral (ligament)
843.1	Ischiocapsular (ligament)
843.8	Other specified sites of hip and thigh
843.9	Unspecified site of hip and thigh
844	Sprains and strains of knee and leg
844.0	Lateral collateral ligament of knee
844.1	Medial collateral ligament of knee
844.2	Cruciate ligament of knee
844.3	Tibiofibular (joint) (ligament), superior
844.8	Other specified sites of knee and leg
844.9	Unspecified site of knee and leg

845	Sprains and strains of ankle and foot
845.0	Ankle
845.00	Unspecified site
845.01	Deltoid (ligament), ankle
845.02	Calcaneofibular (ligament)
845.03	Tibiofibular (ligament), distal
845.09	Other
845.1	Foot
845.10	Unspecified site
845.11	Tarsometatarsal (joint) (ligament)
845.12	Metatarsophalangeal (joint)
845.13	Interphalangeal (joint), toe
845.19	Other
846	Sprains and strains of sacroiliac region
846.0	Lumbosacral (joint) (ligament)
846.1	Sacroiliac (ligament)
846.2	Sacrospinatus (ligament)
846.3	Sacrotuberous (ligament)
846.8	Other specified sites of sacroiliac region
846.9	Unspecified site of sacroiliac region
847	Sprains and strains of other and unspecified parts of back
847.0	Neck
847.1	Thoracic
847.2	Lumbar
847.3	Sacrum
847.4	Coccyx
847.9	Unspecified site of back
955	Injury to peripheral nerves of shoulder and upper limb
959	Injury, other and unspecified
959.2	Shoulder and upper arm
959.3	Elbow, forearm and wrist
959.4	Hand

B. Document Problem Using Injury/Morbidity Databases

A number of sources of information exist that can provide documentation of the extent of the ergonomic hazards and work-related musculoskeletal disorders. Definitions and classifications of work-related musculoskeletal disorders, as well as industrial and occupational coverage, differ among these databases. However, while each of these databases are somewhat limited, they are complementary and provide a collective resource to determine high-risk industries and occupations.

These databases may also provide information on trends in incidence of work-related musculoskeletal disorders. Available databases are:

1. Occupational Injuries and Illnesses in the United States by Industry

This is a national sample conducted annually by the Bureau of Labor Statistics that covers all industries except state and local government and farms with fewer than 10 workers. It does not have information on occupation. The disease category that is relevant is "Diseases associated with repeated trauma." This category is defined by examples: conditions due to repeated trauma, vibration, or pressure, such as carpal tunnel syndrome; noise-induced hearing loss; synovitis, tenosynovitis, and bursitis; and Raynaud's phenomena.

2. Workers' Compensation - Bureau of Labor Statistics (BLS) Supplemental Data System (SDS)

This database contains data on workers' compensation that includes industry and occupation. Diseases are coded by a modified American National Standards Institute (ANSI) Z216.2 classification system that is somewhat more specific than the BLS annual survey. The disease categories that are relevant are sprains and strains; inflammation and irritation of joints, tendons, or muscles; and diseases of peripheral nerves and ganglia. This database also identifies the part of body affected. Therefore, any of these disease categories can be sorted by part of body affected, e.g., inflammation of knees. Examples from the BLS-SDS are attached as Exhibit 1 (available from NIOSH on request). Some disadvantages of this database are that it does not cover all states and in the latest year, 1988, only 14 states were involved. Over the years many more states reported, but never all 50. The reporting parameters also varied. Some states reported closed cases, some reported cases occurring during the year, and some reported cases entered into their system during the year. Some of the data were first reports and a portion of these would not be valid claims. Another disadvantage is that the state laws vary with regard to the number of days of disability required, the requirements for coverage that may exclude chronic conditions, etc. A substantial advantage is that it covers all workers in agriculture, and state and local government.

3. Social Security Disability Data

This is a national database administered by the Social Security Administration that covers permanently disabled workers. A disadvantage is that work relatedness of the disability does not have to be established. Advantages are that it covers all employed workers, diseases are coded according to the ICD [DHHS 1989], industries are coded according to the Standard Industrial Classification (SIC) to the 3-digit level, and occupations are coded by the Dictionary of Occupational Titles. NIOSH analyses of the data, as summarized in Exhibit 2 (available from NIOSH on request) for 1969-72 and 1975-76, give some information on disability by industry and occupation. More recent data could be studied. There is an annual summary of disease categories by major industry division that is included in Exhibit 2. The specificity of the disease classification of this database exceeds that of the two databases described in sections

I.B.1. and I.B.2, and will be more useful for chronic diseases because it is more specific for disease and it is restricted to permanent disabilities. Therefore, the Social Security Disability database is useful for studying chronic diseases.

4. National Health Interview Survey (NHIS) - Core Data

The National Health Interview Survey conducted by the National Center for Health Statistics is an ongoing survey of health conditions in the non-institutionalized, civilian population of the United States. Each year about 50,000 households are surveyed, collecting information on about 120,000 persons. Information is collected on chronic conditions, using six condition lists. Each respondent is administered one of the lists. Conditions that are relevant for the surveillance of work-related musculoskeletal disorders are lumbago; sciatica; slipped or ruptured disc; repeated trouble with neck, back, or spine; bursitis; and any disease of the muscles or tendons. Current estimates from the 1988 NHIS reported 17.7 slipped or ruptured discs per 1,000 persons and 18.4 cases of bursitis per 1,000 persons. Frequencies for the other conditions were not reported. Information on the current occupation of those persons in the workforce is available but there is no definite information on the work-relatedness of the conditions.

5. National Health Interview Survey - 1988 Occupational Health Supplement

In 1988, supplementary questionnaires on various occupational health effects were added to the core questionnaire. Sections related to work-related musculoskeletal disorders were on back pain and hand discomfort including carpal tunnel syndrome. Based on stratified sampling of the population, this supplementary database provides statistically defined estimates of the self-reported conditions for various industry/occupation categories. It includes basic demographic information (age, sex, race, region), prevalence and rate of self-reported and medically-diagnosed carpal tunnel syndrome, back pain, and hand discomfort. Repetition, posture, and vibration are self-reported as exposure indicators for carpal tunnel syndrome. A disadvantage of these data is the cases are self-reported without medical validation. Self-reported cases without validation may result in an overestimate or an underestimate.

6. National Occupational Exposure Survey

The National Occupational Exposure Survey conducted by NIOSH in 1982-83 collected data on a number of ergonomic hazards. It can provide information on the number of workers exposed to a specific hazard by occupation and industry sector. A limitation of this database is that it did not cover all industries, or state and local government. Another limitation is the data were observational and were not quantified. It is important to note that this survey excluded finance, insurance, real estate, restaurants, and government agencies, as well as most of the retail and wholesale trade, agricultural, and marine industries. Ergonomic disorders are a recognized occupational health problem in some of these industries.

NIOSH can provide descriptive analyses for 10 "Chronic Trauma" exposures (whole-body vibration, segmental vibration, passive postures, awkward postures, lifting postures, arm-transport movements, shoulder-transport, hand/wrist manipulations, finger manipulations, machine-paced work) plus two forms of vibration (whole body and segmental) defined in the Survey Manual of the 1981-1983 National Occupational Exposure Survey (NOES) [NIOSH 1988]. The following are the analyses that NIOSH can provide:

(1) Estimates of the number of workers (by gender) potentially exposed to each of the cited chronic trauma and vibration hazards.

(2) Stratification of the estimates described in section I.B.6.(1) by Standard Industrial Classification (SIC).

(3) Stratification of the estimates described in section I.B.6.(1) by 1980 census occupational codes and titles across industries.

(4) Estimates of the national number of facilities by Major Industrial Group (i.e., construction and manufacturing) and by 2-digit SIC in which workers are potentially exposed to ergonomic hazards that were included in the survey.

(5) Estimates of the number of facilities or potentially exposed workers as discussed in sections I.B.1. through I.B.4., produced in tabular form by industrial facility employment size ranges.

7. SENSOR Programs

Several state health departments entered into cooperative agreements with NIOSH in 1987 to pilot surveillance strategies for carpal tunnel syndrome based primarily on physician reporting of occupational disease cases. While the programs had varying success in ascertaining cases, the project resulted in two reports by the California Department of Health Services [1990; 1991]. One was a survey of 515 health care providers in Santa Clara County; the respondents estimated caring for 7,214 cases of carpal tunnel syndrome, of which 3,413 cases (45%) were considered to be work-related. The second report summarizes the demographics, occupation, and industry of the 239 work-related Santa Clara County carpal tunnel syndrome cases reported to the surveillance system in 1989-91; patient questionnaire data, that have not been reported to NIOSH and may not yet have been analyzed, include information on symptoms, treatment, and occupational and non-occupational carpal tunnel syndrome risk factors.

Currently two states (Wisconsin and Massachusetts) are conducting SENSOR-sponsored surveillance for carpal tunnel syndrome. These data will include demographic, occupational, and some treatment and risk factor information on carpal tunnel syndrome cases identified through physician reporting, workers' compensation, and hospital reports of carpal tunnel release surgery. Data sources will include patient questionnaires, review of medical records, employer interviews, and, in select cases, workplace visits.

II. SCOPE AND APPLICATION OF ERGONOMICS STANDARD

NIOSH recommends that the standard be limited to ergonomic hazards that cause or aggravate work-related musculoskeletal disorders as defined in Section I.A., and that the standard apply to all industrial divisions under OSHA jurisdiction. Reasons for this are that all employers should be required to conduct a survey of the workplace to determine if workers are exposed to ergonomic hazards as defined in the standard and to conduct a survey of the workers' medical records to determine if there are reports of work-related musculoskeletal disorders. This approach is recommended for the following reasons. The biomechanical stresses on workers preforming repetitive tasks are extremely complex. Very small changes in initial conditions such as the amount of force exerted, the distance over which the force is exerted, the number of repetitions, the lengths of various bones and tendons in individual workers, the temperature, recovery times, and many other factors may result in extreme changes in the biomechanical stress exerted on various anatomical groups.

There are reports of excess work-related musculoskeletal disorders related to a number of specific job tasks such as upper body complaints among meat cutters in the meatpacking industry [OSHA 1990], hand-wrist problems in grocery checkout workers [Morganstern et al. 1991], knee injuries in carpet layers [NIOSH 1990] and dairy farmers [Anderson et al. 1989]. There are also studies reporting statistically significant increases in hand-wrist disorders and tasks involving high force and high repetition compared to tasks involving low force and low repetition in several industrial classifications [Armstrong et al. 1985].

The Bureau of Labor Statistics (BLS) Supplementary Data System (SDS), based on data from 25 states, reported for 1987 (see Exhibit 1):

- 541,000 cases of sprains and strains: 261,000 of those involved the back and 103,000 involved the lower extremities; 326,000 of these sprains and strains were reported as due to overexertion.
- 25,000 cases of dislocations: approximately one-half of the cases involved the back and one-tenth involved the lower limbs; over one-half were due to overexertion.
- 14,500 cases of inflammation or irritation of the joints, tendons, or muscles: 10,600 of these cases involved the upper extremities and 1,000 involved the lower extremities.
- 10,700 cases of diseases of the peripheral nerves: 8,400 of these involved the upper extremities.

Available surveillance data and NIOSH research and health hazard evaluation (HHE) studies suggest that work-related musculoskeletal disorders may exist in all industrial divisions. For example, in the 1988 BLS data from 14 states, 1209 4-digit SIC codes experienced one or more cases that meet the definition of work-related musculoskeletal disorders. The industries that experienced more than 1000 cases were:

BLS WORKERS' COMPENSATION CASES DUE TO WORK-RELATED MUSCULOSKELETAL DISORDERS (1988)

Industry Description	SIC Code	Number of Cases
Oil & gas field services, NEC*	1389	1158
Residential building construction	1520	1647
Nonresidential building construction	1540	2074
Highway & street construction	1611	3097
Water, sewer & utility lines	1623	1074
Heavy construction, NEC	1629	1305
Plumbing, heating, air conditioning	1711	3145
Electrical work	1731	1731
Plastering, drywall & installation	1742	1552
Roofing and sheetmetal work	1761	1272
Concrete work	1771	1035
Special trade contractors, NEC	1799	1175
Meatpacking plants	2011	2372
Bottled & canned soft drinks	2086	1303
Men's & boy's work clothing	2328	1251

*NEC = not elsewhere classified.

Industry Description	SIC Code	Number of Cases
Sawmills & planing mills, general	2421	1902
Miscellaneous plastics products	3079	3996
Machinery, except electrical, NEC	3599	1027
Motor vehicles & car bodies	3711	1554
Motor vehicle parts & accessories	3714	3195
Trucking, local & long distance	4210	5291
Certificated air transportation	4511	1497
Refuse systems	4953	1926
Groceries & related products	5140	1331
Groceries, general line	5141	1612
Lumber & other building materials	5211	1412
Department stores	5310	1662
Department stores	5311	3786
Grocery stores	5410	3445
Grocery stores	5411	7666
New & used car dealers	5511	1469
Auto & home supply stores	5531	1017
Eating & drinking places	5810	3230
Eating places	5812	5255
Real estate operators & lessors	6510	1335
Hotels, motels, & tourist courts	7010	1081
Hotels, motels, & tourist courts	7011	2385
Building maintenance services, NEC	7349	1212
Personnel supply services	7360	1186
Temporary help supply services	7362	2423
Miscellaneous amusement & recreational services	7990	1184
Nursing & personal care facilities	8050	1844

Industry Description	SIC Code	Number of Cases
Skilled nursing care facilities	8051	4844
Nursing & personal care, NEC	8059	4518
Hospitals	8060	4791
General medical & surgical hospital	8062	9777
Psychiatric hospitals	8063	1498
Elementary & secondary schools	8210	3468
Elementary & secondary schools	8211	5614
Colleges & universities	8221	1688
Residential care	8361	1604

There are 422 occupations at the 3-digit coding level that experienced disability from work-related musculoskeletal disorders. Those occupations with more than 1000 cases of musculoskeletal disorders were:

OCCUPATIONS WITH MORE THAN 1000 WORKERS' COMPENSATION CASES, 1988, 14 STATES, MUSCULOSKELETAL DISORDERS

Occupation	1980 Census Code	Number of Cases
Managers, NEC	019	2651
Management related occupations	020	1505
Registered nurses	095	3931
Licensed practical nurses	207	2342
Health technicians, NEC	208	1263
Sales occupations, supervisors	243	2740
Retail sales workers	260	9365
Secretaries	313	1140
Shipping clerks	364	2598
Stock clerks	365	1810
General office clerk	379	1176

Occupation	1980 Census Code	Number of Cases
Firefighters	417	1914
Police & detectives	418	1793
Waiters & waitresses	435	1618
Cooks	436	2871
Kitchen workers, food preparation	439	1475
Miscellaneous food preparation	444	3025
Health aides, except nursing	446	1433
Nursing aides & attendants	447	15131
Maids & housemen	449	4306
Janitors & cleaners	453	9151
Farm workers	479	2860
Groundskeepers	486	2911
Automobile mechanics	505	2758
Truck mechanics	507	1485
Industrial machinery repairers	518	1442
Specified mechanics, NEC	547	1324
Not specified mechanics	549	2073
Construction supervisors	550	1179
Carpenters	567	4537
Electricians	575	1983
Painters	579	1234
Plumbers, pipefitters	585	2073
Construction trades, NEC	599	1311
Precision production supervisors	633	1649
Machinists	637	1159
Butchers & meat cutters	686	1891
Punching & stamping machine operators	706	1325

Occupation	1980 Census Code	Number of Cases
Molding & casting machine operators	719	1271
Textile sewing machine operators	744	1860
Packaging & filling machine operators	754	1980
Miscellaneous machine operators, NEC	777	6115
Machine operators, not specified	779	4432
Welders & cutters	783	3164
Assemblers	785	9021
Miscellaneous hand workers	795	1122
Production inspectors	796	1627
Truck drivers, heavy & light	804	14623
Driver - sales workers	806	3226
Bus drivers	808	1701
Industrial truck & tractor operators	856	1625
Miscellaneous material moving equipment	859	1132
Helpers, construction trades	865	1232
Construction laborers	869	6708
Production helpers	873	2371
Garbage collectors	875	1496
Stock handlers & baggers	877	5343
Machine feeders & offbearers	878	1622
Freight, material handlers, NEC	883	8523
Garage, service station occupations	885	1180
Hand packers & packagers	888	2042
Laborers, except construction	889	21991
Unclassifiable	999	2145

These data show the pervasiveness of work-related musculoskeletal disorders throughout standard industrial and occupational classifications, and also indicate that certain areas in the same industrial and occupational classifications do not exhibit equal risk. For this reason, NIOSH recommends that all industries be covered by the OSHA ergonomic safety and health management standard. However, NIOSH recommends a two-part approach for addressing ergonomic hazards that would first require the employers to review job tasks and medical records, and second, based on the results of this review, proceed to a complete ergonomics management program. The first step would require the employer to conduct a workplace survey using methods described in section III.A. with concentration on simple methods such as checklists. The employer would also be required to review records in order to determine whether any cases of work-related musculoskeletal disorders are occurring using passive surveillance methods as described in section III.C.1. If there are ergonomic hazards and there is no evidence of work-related musculoskeletal disorders, a person trained in ergonomics should evaluate the ergonomic hazards to determine if there is a significant risk of work-related musculoskeletal disorders. If work-related musculoskeletal disorders are identified or a significant risk of work-related musculoskeletal disorders has been determined, the employer should develop a complete ergonomic management program to abate the ergonomic hazards and reduce the risks of injury.

Further analysis of the existing databases noted in I.B. and the results of ongoing research may identify specific industries, occupations, and job tasks where OSHA should require the development of an ergonomics management program regardless of the results of an employer review.

III. ELEMENTS OF AN ERGONOMICS MANAGEMENT PROGRAM

NIOSH presents in this section five elements of an ergonomics management program: 1) worksite analysis, 2) hazard control, 3) health surveillance, 4) medical management, and 5) training and education. An ergonomics management program should be tailored specifically to each location, its workers, and their unique problems.

Management commitment and worker involvement are critical to the success of an ergonomics management program [OSHA 1990]. Management commitment is demonstrated by a written ergonomics management policy, the establishment of an ergonomic task force or committee, and a commitment to regular review and accountability. Worker involvement is manifested by their role as active participants on the ergonomic task force, providing feedback, identifying potential ergonomic problems, developing solutions related to equipment and work procedures, and providing early reports of symptoms.

A. WORKSITE ANALYSIS

The purpose of worksite analysis (ergonomic hazard evaluation) is to identify hazards that cause work-related musculoskeletal disorders. The ergonomic hazard evaluation process can be divided into two parts. The first stage involves an evaluation of job demands to identify the requirements of the task. In the second stage, job demands are compared to known human capacities. If task requirements do, in fact, exceed the capabilities of the workforce, control measures may be indicated.

Evaluation of Job Demands

The demands of most industrial jobs are a function of the work environment. The work environment can be described in terms of three basic components. These are:

- The tools, machines, parts and materials required for the job.
- The workstation and the physical environment.
- The task, including its content and the organizational environment in which it is performed.

A generic definition of tools may include hand tools, powered tools, machines, computer terminals and keyboards, instruments and their component parts. Traditionally, ergonomic evaluations begin with an investigation of the tools and equipment used in the workplace. Tools that require awkward postures and repeated forceful exertions, or transmit vibration to the hand have been implicated in the development of upper extremity musculoskeletal disorders [Putz-Anderson 1988].

The workstation can include tables and benches, stools and chairs, controls and displays, vehicle cabs, checkout stands, and storage bins. The physical environment includes lighting, noise levels, air quality, temperature, and ventilation. Both factors can have significant effects on comfort and functional ability as well as health. Ergonomic deficiencies in the workstation and physical environment may not be as obvious as tool design deficiencies, and special measurements (e.g., sound, illumination) may be required to identify problematic aspects. Correcting these problems may require greater capital expense (e.g., major facility renovations) than changes in tool design [Snyder et al. 1991].

Finally, task and organizational factors are increasingly recognized as important to the health, safety, productivity and satisfaction of workers. Job content (i.e., simple, routine versus complex, varied duties), work scheduling, work pacing, management style and climate, worker autonomy, feedback, worker support, opportunity for advancement, and training, are variables that can contribute to a positive work environment or, alternatively, produce stress. These "psychosocial" factors have been associated with low back pain in industrial workers and neck-shoulder symptoms in office workers [Linton and Kamwendo 1989; NIOSH 1992a; NIOSH 1992b; Wilson and Grey 1984]. Unfortunately, these factors are often the most difficult part of the work environment to evaluate. Although work rate is usually easy to measure, other problems emanating from job/organization factors are usually less evident from a physical inspection of the workplace and are often far more difficult to correct.

Although some studies may be limited to an investigation of tool and workstation factors, a thorough ergonomic hazard evaluation should examine the interaction of the worker with all three components of the work environment. Some hazards result from interactions between tool, workstation and job design characteristics. To accurately characterize the severity of the hazard, an investigation of all three components is necessary. For example, poor workplace design, involving poor chair design or visual display problems, may have only modest consequences for workers with moderate production demands or for professionals able to exercise control over the work regimen. The same design flaws may have far more important implications for workers with more stringent performance demands or little control over their work regimen.

There are no generic procedures for conducting an ergonomic evaluation of the workplace; the specifics of an investigation are dependent on a number of constraints, and procedures must be tailored to the individual workplace. However, the protocol for conducting an ergonomic evaluation usually follows one of two formats [Putz-Anderson 1988]. One approach, referred to as task analysis, involves adaptations of traditional work measurement methods for the purpose of documenting and measuring exposures to ergonomic stressors. A second approach involves use of an ergonomic checklist. A brief description of each approach is provided below.

Task Analysis. Task analysis refers to a broad spectrum of methods used to analyze observable and covert human behavior for the purpose of identifying the performance demands of jobs and job tasks [Drury et al. 1987]. Once task elements and job demands are determined, the analyst can decide whether these demands fall within the capabilities of workers and whether controls and task modifications are needed [Putz-Anderson 1988; Saito 1987]. Task analysis can lead to workplace redesign or tool developments that will eliminate or reduce the hazards of a task. For example, the task of stretching carpets involved the use of knee kicking tools that damaged the knees of carpet layers. A number of mechanical tools have been developed that can eliminate or substantially reduce the use of hazardous knee kickers [NIOSH 1990].

One method, time and motion analysis, determines what the worker is doing and how it is being done over a given time period. Motion analysis is now used by ergonomists to identify excessive manual repetitions and awkward and static postures of jobs that pose a risk of musculoskeletal disorders. Timed activity analysis can also be useful for analyzing complex tasks, with varying levels of detail including irregular activities, and describing simple tasks with very repetitive, short-cycle job elements [Barnes 1983; Drury 1983]. Putz-Anderson et al. [1992] developed an expanded version of a timed activity analysis for application to complex office tasks. Their goal was to develop an objective method to evaluate stressful job designs that posed a risk to clerical workers for developing musculoskeletal disorders.

Checklists. Ergonomic checklists can be used as an alternative or supplement to task analysis methods. Persons with limited formal training can often use checklists to identify common hazard sources in a fairly short period of time, while ensuring that systematic and standardized procedures are followed. Examples of items that might be found on an ergonomic checklist are described by Lifshitz and Armstrong [1986]. Examples of checklists have also been included in Exhibit 3 (see page 37). Users should be cautioned that most checklists are not comprehensive enough to cover the entire spectrum of risk factors that may be present at any specific worksite. Therefore, existing checklists should be customized and evaluated in a walk-through survey to ensure that the questions are appropriate to the worksite of interest [Putz-Anderson 1988].

Evaluation of Human Capacities

For most biomechanical factors, the limits of human capacity have not been defined. The interaction between normal human biomechanical variables and environmental variables may make it difficult to arrive at general principles that can be applied to specific tasks. Thus, in an ergonomic evaluation, it is difficult to determine if job demands exceed acceptable limits of human capacity. Anthropometric tables can help determine if workstation design is compatible with the user. Other studies provide guidance on normal human strength capacities in particular work situations [Kamon et al. 1982; Mathiowetz et al. 1985]. An epidemiological study across several industries and tasks suggests that workers who are subjected to highly repetitive jobs that also involve high manual force exertion are at greater risk for upper extremity musculoskeletal disorders [Armstrong et al. 1985]. The NIOSH Work Practices Guide for Manual Lifting [1981] is based on studies that indicate that a number of variables, including job factors and personal factors, influence the amount of weight a person can lift without back injury. Formulas for calculating load limits for lifting tasks based on analyses of biomechanical stresses on the lower back, data on the lifting strength capabilities of the working population, and psychophysical studies of acceptable exertion levels have been published [Putz-Anderson and Waters 1991].

Where existing data are insufficient to indicate the magnitude of hazards associated with a particular task, additional indicators of task difficulty are task performance, physiological response, and the worker's subjective assessment of the workload [Meister 1985].

Performance measures. Performance measures quantify the productivity and quality of output by the worker. Job demands that exceed workers' capacities may be manifested by decrements in performance measures [Barnes 1983]. Common performance measures include the following [Meister 1985]:

1. Time
    - Reaction time
    - Activity duration time
2. Accuracy
    - Observation errors
    - Response errors
3. Frequency of Occurrence
    - Number of responses per unit or interval
    - Number of errors per unit or interval
4. Amount Achieved or Accomplished
    - Percent of activities accomplished
    - Degree of success
5. Consumption or Quantity Used
    - Units consumed to accomplish activity
    - Units consumed per unit time

Generally, the best performance measures are those that are objective, quantitative, unobtrusive and easy to collect without specialized instrumentation [Meister 1985].

Performance test batteries can also be used to evaluate worker performance and subjective fatigue. Decrements in performance over the course of a work shift may indicate decreased alertness and increased fatigue due to work place conditions. A successful performance test battery was developed by NIOSH researchers to evaluate fatigue effects from shift work and long workdays [Rosa et al. 1985].

Physiological measures. Physiological measures can be used to evaluate an individual's response to controlled working conditions. Non-invasive monitoring techniques that do not interfere significantly with job performance can be used at the worksite to assess the effects of work demands on individual muscle activity or whole body cardiovascular function. Physiological indicators of whole-body stress include heart rate, blood pressure, oxygen consumption, and body temperature. Indicators of localized stress include surface electromyography (EMG), tremor measurements and ratings of perceived exertion [Meister 1985].

Subjective assessment measures. Subjective ratings of perceived exertion or comfort can be used to measure human capacity. An advantage of perceived exertion ratings is that they integrate information from the peripheral muscles and joints, cardiovascular and respiratory functions, and the central nervous system into a single measure. Perceived exertion scales have been found particularly valuable in studies of short-term static work for which valid physiological measures are difficult to obtain [Rosa et al. 1985].

Inherent deficiencies in the use of subjective measurements are: lack of fundamental units for measuring perceived exertion [Rosa et al. 1985]; the worker may be unaware of the extent to which he/she is stressed, he/she may confuse mental and physical effort, and his/her estimates may change over time [Meister 1985]. Nonetheless, psychophysical scales have been used successfully in a number of ergonomic investigations of work tasks, and high correlations have been demonstrated between subjective ratings and physiological variables [Gamberale 1972].

B. HAZARD CONTROL

Background

The goal of "hazard prevention and control" is to eliminate, reduce, or control the presence of ergonomic hazards. Ergonomic hazards may be identified as a result of performing a worksite analysis--the details of which were discussed in the previous section, Part A.

By definition, "ergonomic hazard" is a recent term chosen to refer to a set of work-related risk factors that are associated with the development of musculoskeletal disorders. Risk factors commonly associated with ergonomic hazards include:
(1) repetitiveness, (2) force/mechanical stress, (3) awkward or static posture,
(4) vibration, and (5) work organizational/stress factors [Armstrong et al. 1986; Arndt 1987].[2] In general, ergonomic hazards are present whenever the work demands of a job

[2]This list of risk factors for work-related musculoskeletal disorders is not intended to be all inclusive.

exceed the capacity of those workers performing the jobs. Moreover, excessive work demands can arise from poorly designed work processes, tools, and/or work stations [Putz-Anderson 1988].

There are many potential ergonomic solutions or interventions for each of the risk factors listed. Table 1 provides examples of relatively simple single-fix solutions that have been recommended by various ergonomic experts for each risk factor [Grandjean 1988; Konz 1979]. To be effective, an ergonomic intervention should serve to reduce the source of the physical stress (i.e., reduce the ergonomic hazard) associated with a particular risk factor. The theory is that by reducing hazard levels, there will be similar reductions in illness and injury rates.

In some cases, proposed ergonomic interventions are simple and consistent with common sense. At the majority of worksites, however, where ergonomic hazards have been identified, a more comprehensive approach is required than can be provided by any of the single-fix solutions, some of which are listed in Table 1. Today, with the complexities of the mechanized work environment, ergonomic solutions often serve as the interface between the "person, machine, and work environment," reflecting the importance of a systems approach to hazard prevention [McCormick and Sanders 1982].

NIOSH continues to support a three-tier hierarchy of controls as an intervention strategy for controlling ergonomic hazards. This position was outlined in the "Ergonomics Program Management Guidelines for Meatpacking Plants" [OSHA 1990]. The approaches identified in that document include the following steps in order of preference:

- Engineering or ergonomic design changes to tools, handles, equipment, workstations, work methods, or other aspects of the workplace, often called engineering controls.
- Changes in work practices or organizational and management policies, sometimes called administrative controls.
- Use of personal protective equipment.

A discussion of each of these approaches follows:

1. <u>Engineering/Ergonomic Controls</u>

The preferred method for control and prevention of work-related musculoskeletal disorders is to design the job to match the physiological, anatomical, and psychological characteristics and capabilities of the worker. In other words, safe work is achieved as a natural result of the design of the job, the work station and tools; it is independent of specific worker capabilities or work techniques.

Although the focus of this section is on hazard control, the concept of prevention is best exemplified when the workplace, tools, work station, and work process are designed from the beginning to accommodate the capability and capacities of the workers. Unlike the majority of occupational hazards, however, sources of ergonomic stress are usually hidden or embedded within the job as specialized patterns of movement or tool usage. The result is that ergonomic hazards are often difficult to predict or anticipate during the initial design stage.

Ergonomics is the discipline that strives to develop and assemble information on people's capacities and capabilities for use in designing jobs, products, workplaces and equipment. The goal of ergonomics is to establish through job design, a "best fit" between the human and imposed job conditions to ensure and enhance worker health, safety, comfort, and productivity.

A number of reference works containing ergonomic guidelines for the design of various workplaces have been compiled by Van Cott and Kincaid [1973], Konz [1979], Woodson [1981], Eastman Kodak [1983; 1986], Putz-Anderson [1988], Tichauer [1991], Chaffin and Andersson [1991], and Mital and Kilbom [1992], among others. These strategies apply both to the design of new jobs and the control of hazards in existing jobs. In general, the selection of a design for limiting musculoskeletal stress will depend on existing technology, resources, and employee acceptance; however, numerous studies indicate that designing or redesigning tools, workstations or jobs in accordance with ergonomic guidelines can be effective in limiting worker exposure to ergonomic hazards (Table 2).

Other studies have examined the effectiveness of engineering changes on the incidence rate of musculoskeletal disorders associated with specific job tasks. In a comparison of three approaches to low back injury control, Snook et al. [1978] concluded that worker selection, and training in lifting technique were ineffective, and that designing jobs to fit the capabilities of workers could reduce low back injuries due to lifting by two-thirds. Westgaard and Aaras [1984; 1985] introduced adjustable work stations and fixtures, and counterbalanced tools in a cablemaking company, and found that turnover and absenteeism due to musculoskeletal complaints were reduced by 2/3 over an eight-year period. Companies that have adopted plant- or corporate-wide ergonomics programs consisting of worker training, union-management participative teams, and job analysis and redesign programs, have reported decreases in musculoskeletal injury incidence rates and turnover, and increased productivity [McKenzie et al. 1985; Rigdon 1992; Lutz et al. 1987; Geras et al. (unpublished); LaBar 1992; Echard et al. 1987]. These and other studies describing the effect of various hazard control approaches on musculoskeletal incidence rates are summarized in Table 3.

2. Administrative Controls

Administrative controls can be defined as policies or work practices used to prevent or control exposure to ergonomic stressors that can result in work-related injury or disease. Examples of administrative controls include the following [OSHA 1990]:

- Work Practices
  - -- Providing frequent rest breaks to offset undue fatigue in jobs requiring heavy labor or high performance/production rates
  - -- Limiting overtime work and periodically rotating workers to less stressful jobs.
  - -- Varying work tasks or broadening job responsibilities to offset boredom and sustain worker motivation.
- Training workers to use work methods that improve posture and reduce stress and strain on the extremities
- Worker placement evaluation

a. Work Practices

Although engineering controls are the preferred method of ergonomic hazard control, there are work situations where modification in work practices may be used as a temporary substitute for engineering controls. Such circumstances, however, should continue to be regarded as potentially hazardous, because the source of the ergonomic hazard remains. Any level of protection afforded by "work practices" is a function of human intervention, that is always subject to the weaknesses inherent in human oversight and control activities. The history of such failures is well documented in the occupational safety and health literature.

Work practices refer to modifications in job rules and procedures that are usually under the control of management or administrators. For example, in office settings where the physical environment (lighting, furniture, and VDT equipment) may already be highly refined and state-of-the-art, changes in work organization and attention to psychosocial factors provide more potential for reducing ergonomic stressors [Kilbom 1988]. Furthermore, administrative controls such as worker rotation, additional rest breaks, and slowing of production rates may be the only method of hazard control available in situations where work tasks are highly variable, there are no fixed workstations, or there are no tools involved in the work (e.g., grocery order selectors, workers in certain types of assembly jobs, sign language interpreters).

The effectiveness of work practice controls has been examined by a number of researchers. One investigation of keyboard operators found that operators who were provided short but frequent rest breaks were more productive than operators receiving only the traditional mid-morning, mid-afternoon and lunch breaks [Swanson et al. 1989]. In a series of four studies of 72 workers performing an overhead assembly task, workers were given control over the duration of their work cycles by initiating a one-minute work pause when needed. Such self-pacing served to minimize local shoulder and arm fatigue, resulting in more consistent levels of performance over the course of the study period [Putz-Anderson and Galinsky 1993].

At a plant employing 124 photographic film rollers, decreasing total work time from 353 to 330 minutes per day, and increasing the number of rest breaks from three to six, resulted in a reduction in cervicobrachial disorder and low back complaints [Itani et al. 1979]. An electromyographic study of five jobs where job rotation had been introduced concluded that job rotation may be more useful for reducing stress associated with heavy dynamic tasks than for reducing static muscular load in "light" work situations [Jonsson 1988a].

b. Training: Worker-Employer

Instructional programs aimed at reducing illnesses and injuries are also frequently promoted as readily available and an economical approach to the control of workplace injury. Training programs range from fundamental instruction on the proper use of tools and materials, to instructions on emergency procedures and use of protective devices. More comprehensive training programs are being developed to prepare the worker to participate in a broader range of worksite safety and health activities. These programs are addressed in Section III.E. of this document.

Because the effectiveness of training programs is difficult to evaluate, the success of many of the training programs has been difficult to establish. Some authors have attributed significant reductions in low back disability and lost time injuries to worker training programs [Glover 1976; Bergquist-Ullman and Larsson 1977]. Other studies indicate that well-planned training programs can have small but significant effects on lifting behavior [Chaffin et al. 1986; Varynen and Kononen 1991].

c. Worker Placement Evaluation

Worker placement evaluation has also been promoted as a method for controlling the risk of overexertion injuries and musculoskeletal disorders. The emphasis here is on matching workers to potentially high-risk jobs, i.e., identifying workers with physical characteristics that will enable them to satisfy job demands that may be excessive to other workers. Worker selection or hiring based solely on physical capacities is generally illegal, as a result of the U.S. Federal Rehabilitation Act of 1973 (29 USC[3] §791 et seq.) and the recent Americans with Disabilities Act of 1990 (42 USC §12101 et seq.). However, once a worker is offered a job, he or she can be tested to determine his or her capabilities as a prelude to job placement.

The success of any placement program is dependent on obtaining accurate information on actual job demands as well as with the accuracy of measurements of worker capacities as they relate to the key job demands. A person's capacity for physical work is almost never a single value; it is determined by several factors including the intensity of the effort; the time of continuous effort; the frequency of repeating the effort; the presence of environmental or mental stressors, such as heat, humidity, and time pressure; and individual characteristics such as age, fitness, and skill level [Rodgers 1988].

[3]United States Code

To be valid, work capacity tests must be specific to each job of concern. Furthermore, it must be demonstrated that not only does a worker require the capacity to do the work, but that people without that capacity cannot do the job. For example, it is generally accepted that muscular strength is an appropriate job-related criteria for manual materials handling work. However, it is frequently difficult to measure the strength capacities of the worker that most closely reflect those key strength requirements of the job. Moreover, a worker's maximum strength may have little relationship to his or her ability to exert effort frequently or for long durations. Finally, there are many workplace situations where the job demands change.

In some manufacturing operations, products may frequently change, certain seasons may add environmental stresses, and overtime may change the effort requirements. Thus, the assessment of job demands will not be so accurate that it can be relied upon to predict a worker's success or failure on the job in all situations [Rodgers 1988].

There is some epidemiological support for the idea that strength testing could be a useful means of reducing back injury rates. In studies where the appropriate measurements have been made, a higher incidence of back injuries and back pain was found in those jobs demanding high exertion in relation to the worker's own maximal isometric strength [Keyserling et al. 1978; 1980]. However, to date, there are no valid methods for identifying "high risk people," i.e., accurately predicting whether healthy workers are susceptible to musculoskeletal injury from jobs requiring manual lifting and other forms of exertion. Although the use of X-rays, muscle strength tests, tests of physical fitness or flexibility, or other means have been promoted as screening procedures in the past, thus far none have proved successful [Putz-Anderson 1988].

The American Occupational Medical Association concluded that many of these tests should not be used as screening procedures, but rather as special diagnostic procedures available to the physician on appropriate indications for study [Rothstein 1984].

In summary, an advantage of administrative controls is that they can usually be implemented quickly and easily without the need to purchase or modify equipment. Because administrative controls, however, fail to eliminate the source of the hazard, they should be considered temporary solutions for controlling exposure until more permanent engineering controls can be implemented.

3. Personal Protective Equipment

NIOSH continues to support OSHA in recommending personal protective equipment (PPE) as the least preferred intervention strategy for controlling ergonomic hazards [OSHA 1990]. PPE seldom provides complete protection from exposure to a significant hazard; rather it seeks to reduce the exposure to a level that is acceptable [Moran and Ronk 1987].

Traditionally, PPE has afforded protection to the worker by providing a barrier between the worker and the hazard source. Examples of PPE that operate on this principle include respirators, ear plugs, vibration-attenuating gloves, protective eye wear, chemical aprons, safety shoes and thermal protective clothing. Because braces, wrist splints, back belts, and similar devices do not provide a barrier between the worker and the ergonomic hazard, they cannot be considered PPE. Furthermore, most devices (such as braces and splints) that are purported to reduce biomechanical stress on the musculoskeletal system have questionable value. Indeed, there is little research evidence to demonstrate that these devices limit the risk of injury.

Although other examples may exist, the only obvious example of ergonomic PPE that could be identified is vibration-attenuating gloves. Depending on their composition and construction, gloves have been shown to be effective at absorbing much of the vibration energy that would otherwise be transmitted to the hand [Goel and Rim 1987]. However, potential users should be cautioned that gloves generally interfere with grip strength and manual dexterity, thereby increasing the effort required for manual tasks [Mital and Kilbom 1992].

NIOSH has recently revised the lifting equation to reduce and prevent back injuries [Waters et al. 1991]. This equation is an update of the original equation provided in the *Work Practices Guide for Manual Lifting* [NIOSH 1981]. The new equation addresses jobs that require twisting motions and for which the horizontal and vertical positions of the load and the hand/container coupling can be defined. It re-emphasizes the use of engineering methods in preference to administrative procedures for control lifting hazards.

NIOSH will prepare a position statement on the use of back belts to reduce and prevent low back injuries. This statement will be sent to OSHA in the near future.

Conclusion

Preventing or reducing ergonomic hazards is frequently difficult for a number of reasons. In some cases, several factors combine to create a hazard. Overlapping problems can include high production demands, faulty work methods, awkward work station layouts, and ill-fitting tools [Putz-Anderson 1988]. Therefore, improvements addressing one factor may not eliminate the overall risk. Also, interventions effective in one situation may be ineffective in other settings. Most control plans involve compromise and trade-offs to arrive at the most appropriate solution. The solutions will typically require a series of adjustment or fitting trials to ensure effectiveness and worker adoption. In the final analysis, most ergonomic solutions to work-related musculoskeletal disorders are more often affected through incremental and cumulative improvements in the workplace than from a single, major workplace modification.

In summary, NIOSH continues to support a three-tier hierarchy of control (i.e., engineering controls, administrative controls, and PPE) for controlling ergonomic hazards. The effectiveness of any type of hazard control or prevention program is dependent on management commitment and employee participation. Regular monitoring, positive reinforcement, and feedback are necessary to ensure that control policies and procedures are not circumvented for convenience, schedule, or production.

C. HEALTH SURVEILLANCE

General Principles

This section outlines suggestions for development and use of a workplace health surveillance program to identify, record, track and ultimately prevent and reduce work-related musculoskeletal disorders.

Surveillance has been defined as:

> "The ongoing systematic collection, analysis and interpretation of health and exposure data in the process of describing and monitoring a health event. Surveillance data are used to determine the need for occupational safety and health action and to plan, implement and evaluate ergonomic interventions and programs" [CDC 1988].

Components of a Surveillance System

The health surveillance program for a workplace should incorporate both passive surveillance and active surveillance elements.

Passive surveillance is the collection and analysis of data obtained from existing record sources to identify patterns of disease within a workplace group. The record sources are usually readily available and may be used to determine if a work-related musculoskeletal disorder exists, and to detect disease trends in the group at risk.

Active surveillance involves the development of a system to obtain data with which to determine the patterns or trends of work-related musculoskeletal disorders with greater sensitivity than a passive surveillance system. That is, active surveillance might identify symptoms that may be indicators of developing work-related musculoskeletal disorders not captured by classic case definitions, as in the ICD, or identifies factors that may put workers at greater risk for work-related musculoskeletal disorders.

1. Passive Surveillance

Information Sources: Record systems or information used for passive surveillance generally are collected for purposes other than surveillance. Types of records that have been successfully used in passive surveillance systems, include OSHA 200 logs, plant clinic records or nurses logs, workers' compensation records, insurance claims, and accident reports. Other records that might be used include absentee records, job transfer applications, and other documented problems about particular jobs.

Evaluation of information: Review of information should occur routinely, e.g., yearly, but the frequency of which may be dependent upon the extent of the problem of work-related musculoskeletal disorders. Specific diagnoses may be coded according to the current version of the International Classification of Diseases (ICD). Calculation of job-specific incidence rates (rate of work-related musculoskeletal disorders appearing for the first time during a specified period), and job-specific prevalence rates (rate of all work-related musculoskeletal disorders occurring during a specified period) will help to identify jobs in which workers have work-related musculoskeletal disorders or are suffering physical discomfort from the jobs. The severity of the problem may be determined by examining the number of disability days.

Incidence (new case) rates (per 100 worker-years per year) may be calculated as follows:

$$\frac{\text{\# new cases during the past 12 months x 200,000 hours}}{\text{\# work hours during the past 12 months}}$$

Prevalence rates (all cases during the period) (per 100 worker-years per year) may be calculated as follows:

$$\frac{\text{total \# cases in the past 12 months x 200,000 hours}}{\text{\# work hours during the past 12 months}}$$

Limitations: Passive surveillance is limited by a number of factors, most of which are specific to the types of information being used. Some information sources, such as the OSHA 200 logs and clinic logs provide varying data quality, particularly in completeness (capture of all appropriate events) and accuracy of entries. Medical logs may also be variable due to the availability of an onsite clinic, management's attitude about the use of the clinic, and training of the clinic staff about occupational safety and health.

Information obtained through workers' compensation records, insurance records and personal medical provider records may vary due to a number of factors. These factors include: a worker's likelihood or ability to seek and obtain medical care, the ability or likelihood of the medical care provider to diagnose work-related musculoskeletal disorders correctly, and variations in data recording in the various record sources.

Surveillance data will be limited by information biases of various types. For example, health outcomes can be misclassified as a result of non-uniformity in the methods used by different data sources to classify specific health conditions. In addition, there will be some degree of underreporting in comparison to questionnaire-defined symptoms that appear to be a more accurate measure of the rate of symptoms and disorders. In general, neither of these problems is a serious problem for a passive surveillance system in which an effort has been made to establish some simple uniform reporting criteria and in which there are no major disincentives for workers to report their health problems. Moreover, the problem of health outcome misclassification is also mitigated by the fact that analysis of this type of data is generally done by body region.

2. Active Surveillance

Data Sources: Data can be obtained through periodic worker health surveys. The surveys should collect information on current and past symptoms, anatomical location, and duration and frequency of the symptoms. An advantage of questionnaires is that they are usually easy to administer and provide a quick method for identifying worker's perceptions of hazards and sources of discomfort. One particularly common and easy-to-use format is the "body part discomfort survey." The worker is given a picture of the body and asked to rate the level of comfort/discomfort experienced in different parts [Corlett 1976]. Similarly, the chief advantage of questionnaires and interviews is that they are often successful at eliciting information about job-related complaints and symptoms that would otherwise go undocumented. If large numbers of workers in a specific job or department report job-related discomfort, an investigation of tool, workstation layout, or job design may be indicated.

Symptoms have been the principal method to determine the prevalence and incidence of work-related musculoskeletal disorders in several scientific studies [Siverstein et al. 1986; Bongers 1992; Pope et al. 1991]. Symptoms have been one of the principal outcome measurements in studies of the effectiveness of therapeutic procedures including surgical procedures and exercise programs [Silverstein et al. 1988]. Not only have ergonomists traditionally used changes in the symptoms by body region to evaluate the effectiveness of intervention efforts that lead to redesigned work station layouts and processes, but in NIOSH studies it has been found that over seventy percent of workers with moderate or severe symptoms have at least one positive physical finding on a concurrent physical examination [Baron et al. 1992].

A simple questionnaire should be used that is based on the questionnaire in the OSHA Ergonomics Program Management Guidelines for Meatpacking Plants [OSHA 1990]. Alternatively, the standardized Nordic questionnaires are acceptable for the analysis of musculoskeletal symptoms or a simple postural discomfort scale [Kuorinka et al. 1987].

A questionnaire should identify the location of symptoms, whether they are present at the time the questionnaire is administered, and some measures of their severity. The advantage of the simpler questionnaires is that a smaller facility with limited resources could easily administer and analyze the data. The slightly longer surveys are still easy to administer, but would allow a more sophisticated analysis of the problem, particularly for companies with a large workforce or multiple facilities.

Written questionnaires are relatively inexpensive to administer--workers can complete them at their convenience, and responses can be kept anonymous. A limitation of questionnaires, however, is that they can yield limited information. Symptom surveys are usually sensitive to work-related musculoskeletal disorders, but are poor at discriminating specific disorders or indicating the cause of the complaint. Factors such as the length of the questionnaire, the wording of the instructions, and the time and method of administration have a significant impact on the rate of response and the reliability of the data.

Evaluation of Data: Job-specific incidence and prevalence rates can be calculated using a variety of case definitions, e.g., symptoms only or symptoms and an abnormal physical examination, neither of which are found in passive surveillance data. Information on the severity and frequency of symptoms should be used in determining which problems should be given the highest priority. The definitions and formulas for calculation of incidence and prevalence are included in the section on Passive Surveillance.

Frequency of Surveys: Surveys should be initiated as follows:

a. When evidence from passive surveillance or job analysis suggests an increase in work-related musculoskeletal disorders or a preponderance of ergonomic stressors;

b. Before and after institution of new jobs/tasks/tools/and process changes;

c. When new workers are hired, they should complete a symptom questionnaire prior to beginning work.

Limitations and Issues on Active Surveillance:

a. Active surveillance programs are generally more costly to conduct than passive surveillance;

b. Active surveillance programs depend on the accuracy of worker responses;

c. Questions must be worded so that they are understood by the workers, e.g., pretest the questions to insure that the respondents understand the information that is needed and multi-lingual versions should be created if needed;

d. Workers must understand the purpose of the surveys;

e. The effect of repeatedly asking the same questions over an extended period, as in yearly or periodic health interviews, has not been determined.

D. MEDICAL MANAGEMENT

A medical management program should promote early detection and prompt recovery from work-related musculoskeletal disorders when these disorders are not prevented. The program should also prevent aggravation of musculoskeletal disorders that could occur in workers due to non-occupational activities. Not only can work cause these disorders but it can aggravate them. The specific goals of medical management are the elimination or reduction of symptoms and functional impairment, and a return to work in a manner consistent with protecting the health of the worker.

Effectiveness

There is evidence that early treatment of low back pain and work-related musculoskeletal disorders of the upper extremity reduces their severity, duration of treatment and ultimate disability [AAOS 1991; Flowerdew and Bode 1942; Thompson et al. 1951; Haig et al. 1990; Leavitt et al. 1971; Frymoyer et al. 1983; Lutz and Hansford 1987; Mayer et al. 1987]. Accordingly, medical management policies that encourage workers to report symptoms early and employers to send their symptomatic worker for prompt medical evaluation and treatment may reduce the long-term severity and disability from these work-related musculoskeletal disorders. In addition, these policies create the conditions for an effective health surveillance system.

Because the scientific studies suggest that early intervention may be more effective than late intervention, and since, in general, the cost of care generally increases as these disorders become severe and chronic, medical management protocols should be directed at both mild and severe disorders. The evaluation and treatment approaches for early, mild or intermittent disorders are generally simple and can be provided by many different types of health care providers.

Medical Management Protocol Requirements

1. General Principles of Medical Management

Several principles should underlie the development of either voluntary or mandated medical management protocols. These include:

a. definition of work-related musculoskeletal disorders,

b. promotion of early reporting of symptoms and the avoidance of disincentives (e.g., reprisal) that may discourage reporting,

c. prompt access to care by the symptomatic worker,

d. the emphasis of non-surgical, therapeutic measures (e.g., rest) over surgical procedures in most cases, and

e. medical monitoring following an injured worker's return to work to prevent the recurrence of the disorder; and

f. establishment of an appropriate recovery period.

The clinical course of most work-related musculoskeletal disorders can be divided into three phases: acute (less than one month from the onset), subacute (one to three months), and chronic (greater than 3 months). Chronic disorders that are severe enough to prevent return to work are associated with a poor prognosis. In an attempt to alter this poor prognosis, a number of comprehensive rehabilitation programs have been developed. There is limited evidence that these programs may be partially successful in returning injured workers to employment [Feuerstein 1992].

2. Health Care Provider

Any health care provider with training in work-related musculoskeletal disorders who is licensed and/or registered and practicing within the scope of their license and/or registration could develop a medical management protocol. However, the concepts of primary and secondary prevention should be incorporated in the training of the health care providers. Training and education should be strongly encouraged that address the causes of work-related musculoskeletal disorders, appropriate methods of clinical evaluations, identification of job hazards by workplace inspection, review of written job description or videotape recording of work processes, and the benefits of early evaluation should be strongly encouraged.

3. Job Evaluations

Job evaluations are predictive to some extent of risk of developing work-related musculoskeletal disorders. As discussed earlier, the overall epidemiological, biomechanical, and psychophysical laboratory studies support the basic hypothesis that physical job factors such as force, repetition, and awkward posture are associated with elevated rates of symptoms and disorders. A reasonable extension of this body of scientific studies is that workers with work-related musculoskeletal disorders are at higher risk if they continue to be exposed once the condition develops.

4. Periodic Walkthroughs

These have been recommended in the OSHA Meatpacking Guidelines [OSHA 1990]. As stated earlier in this section, the health care provider should understand the specific job risk factors for each patient or worker who is being evaluated.

5. Rehabilitative Medical Management

As stated earlier, evidence exists to support early intervention and treatment of work-related musculoskeletal disorders in order to decrease the cost, severity, and days of disability. The following recommendations are not meant to substitute for sound medical practice. Standards of medical care change over time; therefore, it is the responsibility of the treating health care provider to render care consistent with current clinical practice.

a. Early Reporting

All workers should receive training regarding the signs and symptoms of work-related musculoskeletal disorders and be encouraged to report such symptoms to their employer. Such reporting allows for prompt evaluation, and, if necessary, treatment of the symptoms. Early treatment of many medical conditions, including musculoskeletal disorders has been shown to reduce their severity, duration of treatment, and ultimate disability [Flowerdew and Bode 1942; Thompson et al. 1951; Haig et al 1990; Leavitt et al. 1971; Frymoyer et al. 1983; Lutz and Hansford 1987; Mayer et al. 1987]. Workers must not be subject to reprisal or discrimination based on such reporting. Employers should also address any financial or other disincentives that discourage workers from reporting their symptoms.

b. Access to Care

Workers reporting signs and/or symptoms suggestive of work-related musculoskeletal disorders should be evaluated by an appropriate health care provider before the worker's next workshift. This is consistent with the risk of continued exposure as discussed earlier.

c. Summary of Health Care Providers' Evaluation

The health care provider who recommends a specific treatment plan for a symptomatic worker should first conduct a medical history to obtain an appropriate characterization of the symptoms, description of work activities, and a past medical history including past trauma to the symptomatic area, prior treatment of musculoskeletal disorders, non-work activities such as hobbies, and other existing diseases.

In assessing the role of work in causing musculoskeletal symptoms and disorders and determining whether a symptomatic worker can continue to work safely, the health care provider will, in general, need to understand the worker's job tasks by visiting the workplace, viewing jobs tasks recorded on videotape, reviewing written description of job tasks, and results of job analysis.

d. Interventions

Resting the symptomatic area, and reduction of soft tissue inflammation are the mainstays of treatment [Howard 1937; Howard 1938; Thompson et al. 1951; Thorson and Szabo 1989; Chipman et al. 1991; Moore 1992; Rempel et al. 1992]. The symptomatic area can be rested by:

(1) Reducing or eliminating worker exposure to biomechanical stressors (forceful exertions, repetitive activities, extreme or prolonged static postures, vibration, direct trauma). This is best accomplished by engineering controls in the workplace.

(2) When engineering controls are not feasible, or until effective controls can be installed, worker exposure to ergonomic hazards can be reduced through restricted duty, rest breaks, job rotation, or temporary job transfer. The principles of restricted duty and temporary job transfer are to reduce or eliminate the total amount of time a worker is exposed to ergonomic stressors [Lederman and Calabrese 1986; McKenzie et al. 1985]. A list of jobs with the lowest ergonomic risk should be developed. The ergonomic risk factors and the muscle-tendon groups required to perform those jobs should be listed.

The precise amount of work reduction for workers on restricted duty cannot be determined; however, the following principle applies: the degree of restriction should be proportional to symptom severity and intensity of the job's biomechanical stressors. Likewise, caution must be used in deciding which jobs are suitable for job transfer because differing job titles may pose the same biomechanical demands on the same muscles and tendons [OSHA 1990].

(3) Complete removal from the work environment should be reserved for severe conditions, or in workplaces where the only available jobs contain biomechanical stressors that would aggravate the existing condition.

(4) Immobilization devices, such as splints or supports, can help rest the symptomatic area [Howard 1937; Howard 1938; Thompson et al. 1951; Thorson and Szabo 1989; Chipman et al. 1991; Moore 1992; Rempel et al. 1992]. These devices are especially effective off-the-job, particularly during sleep. Wrist splints, typically worn by patients with possible carpal tunnel syndrome, should not be worn at work unless the health care provider determines that the worker's job tasks do not require wrist deviation or bending [Putz-Anderson 1988; Kessler 1986]. Immobilization should be prescribed judiciously and monitored carefully to prevent muscle atrophy [Rempel et al. 1992; Curwin and Stanish 1984]. These recommendations do not preclude use of immobilization devices for patients with special needs due to underlying medical conditions.

(5) The health care provider should evaluate an injured worker's hobbies, recreational activities, and other personal habits that result in exposure to biomechanical stressors and advise the worker about the effects of continued exposure [Thorson and Szabo 1989; Chipman et al. 1991; Moore 1992].

e. Treatment for Soft-Tissue Inflammation

(1) Cold Therapy

Although no clinical trials have been performed on the effectiveness of cold therapy on the affected area, most clinicians consider this useful to reduce the swelling and inflammation associated with tendon-related disorders [Thorson and Szabo 1989; Chipman et al. 1991; Rempel et al. 1992; Simon 1991]. Cold therapy has effects on the local circulatory system (vasoconstriction) [Olson and Stravino 1972; Thorsson et al. 1985], and local muscle-tendon tissue (decreased metabolism) [Yackzan et al. 1984]. This reduced supply and demand for blood results in reduced effusion, edema, and swelling. In addition to pain reduction from the reduced swelling, cold therapy reduces the nerve conduction from pain receptors [Kaplan and Tanner 1989].

(2) Oral Anti-Inflammatories

Most clinicians consider these agents (aspirin or other non-steroidal anti-inflammatory agents) useful to reduce the severity of symptoms either through their analgesic or anti-inflammatory properties [Howard 1937; Howard 1938; Thompson et al. 1951; Thorson and Szabo 1989; Chipman et al. 1991; Moore 1992; Rempel et al. 1992; Simon and Mills 1980].

(3) Steroid Injections

For some disorders resistant to conservative treatment, local injection of an anesthetic agent with a corticosteroid may be indicated [Howard 1937; Howard 1938; Thompson et al. 1951; Thorson and Szabo 1989; Chipman et al. 1991; Moore 1992; Rempel et al. 1992].

(4) Ancillary Treatment Modalities

There is little scientific information that either establishes or refutes the efficacy of other treatment modalities for diagnoses encompassed under the term, work-related musculoskeletal disorders. Most clinicians consider physical and occupational therapy a valuable adjunct for treatment through its use of stretching and strengthening programs [Thorson and Szabo 1989; Chipman et al. 1991; Rempel et al. 1992; Curwin and Stanish 1984; Lane 1991].

(5) Referral to Specialists

Many, if not most, work-related musculoskeletal disorders improve with the above conservative measures. If the symptoms do not improve within the expected time frames, referral to an appropriate specialist is indicated. The expected time frame for resolution of symptoms depends on the type, duration, and severity of the condition, in addition to the underlying health of the worker.

Precise time intervals for follow-up evaluation, referral, improvement, and recovery cannot be stated in this submission. Algorithms to assist occupational health nurses through the process of evaluating, treating, and follow-up of workers with work-related musculoskeletal disorders have been developed [OSHA 1990; Hales and Bertsche 1992]. These algorithms are not meant to dictate medical practice, but to provide guidance to practicing occupational health nurses.

E. TRAINING AND EDUCATION

The successful implementation of the worksite analysis, hazard control, health surveillance, and medical management elements of the ergonomics management program requires the active and informed involvement of all members of the organization. This applies not only to those employees directly at risk, but also to those whose job responsibilities may influence the ergonomic risks of others (e.g. supervisors, managers, engineers, and purchasing agents). It is, therefore, essential that all risk-related individuals be equipped with the necessary knowledge, skills and incentives to effectively support and participate in the ergonomics management program. Indeed, the absence of this training may itself be viewed as a risk factor, affecting the well-being of the individual worker and the functioning of the organization [Blackburn and Sage 1992].

Training, when used as part of an overall ergonomics management program, has been shown to effectively enhance worker awareness of ergonomic risks [Liker et al. 1990] and protective behaviors [St-Vincent et al. 1989]. A summary of relevant research is presented in Table 4. It should be noted that successful training programs are not intended to be used in isolation or in lieu of engineering, administrative, and PPE controls (as identified in Section III.B.). Rather training programs are intended to enhance the capacity to effectively recognize workplace hazards and to understand and apply appropriate control strategies. It must also be emphasized that even the most effective training program does not insure that skills and practices learned in the training environment will be enacted and sustained in the workplace. A host of factors including the level of organizational commitment, supervisory support, availability of needed resources and equipment, performance feedback, motivational incentives, opportunity for practice, and workplace norms influence the effectiveness of workplace safety practices independently of the quality of training [Goldstein 1975; Campbell 1988; Baldwin and Ford 1988]. For this reason, the training program must be seen as but one element in the organization's overall ergonomics management program.

Training Model

The planning, execution, and evaluation of ergonomic training should follow the model presented in the OSHA voluntary training guidelines [OSHA 1992] which consists of the following steps:

1) Determining if training is needed
2) Identifying training needs
3) Identifying goals and objectives
4) Developing learning activities
5) Conducting the training
6) Evaluating program effectiveness
7) Improving the program

A general description of how these steps should be implemented in an ergonomics training program is provided below.

1. Determining if Training is Needed

Any worksite requiring an ergonomics management program (as determined by the worksite analysis and medical survey described in Section II) should be required to provide its employees with the training necessary to develop the knowledge and skills to effectively implement the program. Consistent with the approach specified for ergonomic training in related documents [OSHA 1990; NOHSC 1992; Cal/OSHA 1992] training should be provided at two levels:

a) General awareness training for all individuals affected by the ergonomics management program. This may include, in addition to employees directly at risk, supervisors, managers, engineers, purchasing agents, and safety and health committee members whose job responsibilities are related to risk recognition and control.

b) Job/risk-specific training for those individuals and their supervisors employed in high risk jobs as identified by the worksite analysis and medical survey data.

Baseline training at both levels should be provided to all employees during the implementation phase of the ergonomics management program, or at the time of hire for new employees.

2. Identifying Training Needs

a) General Awareness Training

A number of general awareness courses regarding the nature and control of ergonomic hazards are currently available through federal (e.g., NIOSH, OSHA Training Institute), university (e.g., continuing education programs at 12 of the 14 NIOSH-funded Educational Resource Centers), and labor organizations (e.g., Workplace

Health Fund). Model course contents have also been proposed by Rohmert and Laurig [1977] and Smith and Smith [1984]. At a minimum, all individuals receiving general awareness training should be sufficiently informed as to be able to:

1) Describe the general nature, symptoms, and types of work-related musculoskeletal disorders

2) Describe the risk factors associated with work-related musculoskeletal disorders

3) Describe the prevention and control strategies for abating ergonomic hazards

4) Describe the organization's procedures and policies regarding the reporting of work-related musculoskeletal disorders

5) Describe the organization's procedures and policies for reporting perceived ergonomic risks

6) Describe the membership, structure, and general operation of the organization's ergonomic management program

7) Regulations, standards, etc. regarding ergonomic hazards

b) Job/Risk-Specific Training

In addition to the awareness training described above, additional job/risk specific training should be provided to those employees and their supervisors who are at risk from ergonomic hazards as identified in the worksite analysis and medical survey. The content of this training will be dictated by the findings of the worksite and health surveillance activities. Nevertheless, at a minimum, the training should enable the employees to demonstrate an understanding of the:

1) Specific tasks or operations associated with their jobs which pose ergonomic risks (results of worksite analysis)

2) Proper use of tools, devices, and equipment provided to control identified risks

3) Proper engineering, work practice, and administrative controls available to reduce identified risks

4) Procedures for recommending job redesign or control strategies for reducing risk

3. Identifying Training Objectives

Following a determination of the training needs, performance objectives should be specified. Objectives should be clear, directly observable, measurable, and action-oriented. The objectives should describe exactly what the trainee should know and be able to do following training [Gagne and Briggs 1979] and specify the conditions under which these behaviors should be performed [Smith and Delahaye 1987; Komaki et al. 1980]. Because of the variability of ergonomic hazards and related controls across job operations and worksites, training objectives will be situationally specific. Objectives will be identified by the medical surveillance, worksite analysis, and hazard control components of the program.

4. Developing Learning Activities

The mode or method of training should be tailored to the individual worksite and job/task. Size of the organization and available resources, worker demographics, the nature of the work being performed, and other factors will influence the type of learning activities most appropriate. Regardless of the strategy employed, allowance should be made for active rehearsal of the trained skills and behaviors, performance feedback both during training and on-the-job, and remedial or additional instruction when initial training fails to provide trainees with skills and knowledge stated in the course objectives.

5. Conducting the Training

The training should be conducted at a language and educational level compatible with backgrounds of the individuals to be trained. Individuals should be provided with an overview of the materials to be learned as the goals and objectives of the training. This will allow the trainees to determine if they have received adequate instruction relative to organizational expectations. Even materials that are well-learned during training will have to be periodically refreshed. The question here is when or how often should retraining be provided following the initial baseline training to ensure maintenance of the knowledge and skills specified in the goals and objectives. From an empirical perspective, the question is unanswerable in a generic sense. Few systematic field studies of training techniques and retention rates have been conducted to date, and those that are available, vary along important dimensions. Rubinsky and Smith [1971], for an example, report that the positive effects of training on the safe use of grinders using a simulated accident technique began to diminish after only four weeks. The safe donning of self-contained, self-rescuer respirators showed a degradation of skills three months following training [Vaught et al. 1988]. A 30 to 45 minute slide presentation on the proper use of equipment and tools, housekeeping and general safety procedures increased safe work behaviors among vehicle maintenance workers, relative to baseline levels, for up to 45 weeks after training when supervisory feedback was provided 2-3 times a week [Komaki et al. 1980]. The retention rates of learned behaviors vary as a function of a multitude of content (e.g., complexity and nature of the task), trainee (e.g., motivation, aptitude), instructional design (conditions of practice, sequencing of materials) and environmental/organizational (e.g., corrective feedback, reinforcement) variables [Kyllonen and Alluisi 1987; Fendrich et al. 1988].

At a minimum, refresher training (both awareness and job/risk specific) should be provided annually to maintain employee motivation, to reaffirm organizational commitment, and to allow a forum for employee feedback, all factors which have been shown to greatly affect the transfer of training [Baldwin and Ford 1988; Campbell 1988]. In addition, targeted training should be delivered on an "as needed" basis when the medical surveillance data or worksite analysis of an existing or modified job indicate a training need.

6. Evaluating the Program

A plan for evaluating the effectiveness of the training should be developed at the same time that the course objectives and content are formulated. The evaluation should focus on the skills and knowledge specified in the training objectives and provide information on the extent to which the training brought attendees to the desired level of proficiency. The evaluation should occur at two levels [Cole et al. 1984]. The first, a formative evaluation, is conducted concurrently with, or immediately after, training to assess the clarity, organization, and comprehensibility of the instruction. This is to assure that individuals are learning what they should be learning. Surveys, focus groups, interviews, self-assessment tests, and behavioral demonstrations are common methods for formative evaluation. Information learned here should be used to refine the training program.

The second type of evaluation is a summative evaluation which is conducted following the return to work to determine if individuals are actually practicing what they have learned. On-the-job performance, worksite analysis (Section III.A.), and illness and injury data (Section III.C.) may be used for this purpose. If the formative evaluation indicates that learning occurred, but the summative evaluation indicates no change in organizational performance, this may indicatethat the training was not relevant to the actual job/task, or that other aspects of the overall ergonomics management program (e.g. supervisory support, availability of resources, and perceived management commitment) may be deficient.

7. Improving the Program

If the evaluations performed above indicate that the training did not meet objectives, review of the training program, along with the other elements of the ergonomics management program, should be performed and revisions made.

LIST OF REFERENCES ON ERGONOMICS

The following is a list of references generated by NIOSH that are relevant to ergonomic hazards or work-related musculoskeletal disorders.

AAOS [1991]. Clinical policies. DeQuervain's stenosing tenosynovitis (pages 1-2), low back musculoligamentous injury (sprain/strain) (pages 3-5), carpal tunnel syndrome (pages 11-12), and herniated lumbar disk (pages 18-19). Chicago, IL: American Academy of Orthopaedic Surgeons.

Anderson C, Treuhaft PS, Pierce WE, Horvath EP [1989]. Degenerative knee disease among dairy farmers. In: Dosman JA, Cockcroft DW, eds. Principles of health and safety in agriculture. Boca Raton, FL: CRC Press, Inc.

Armstrong TJ, Fine LJ, Silverstein BA [1985]. Occupational risk factors: cumulative trauma disorders of the hand and wrist. Final report on contract 200-82-2507, December 11, 1985.

Barnes RM [1983]. Motion and time study, design and measurement of work. 7th ed. New York, NY: John Wiley & Sons.

Baron S, Hales T, Fine L [1992]. Evaluation of a questionnaire to assess the prevalence of work-related musculoskeletal disorders. In: Hagberg M, Kilbom Å, eds. Stockholm, Sweden: Proceedings of the International Scientific Conference on Prevention of Work-Related Musculoskeletal Disorders, PREMUS, May 12-14, 1992, pp. 39-41.

Bongers PM, de Winter CR [1992]. Psychosocial factors and work-related musculoskeletal disease. In: Hagberg M, Kilbom Å, eds. Stockholm, Sweden: Proceedings of the International Scientific Conference on Prevention of Work-Related Musculoskeletal Disorders, PREMUS, May 12-14, 1992, pp. 46-48.

California Department of Health Services [1990]. Work-related cases of carpal tunnel syndrome in Santa Clara County 1987 -- a survey of health care providers. Berkeley, CA: California Department of Health Services, Surveillance report SR-88-002.

California Department of Health Services [1991]. Cases of carpal tunnel syndrome reported to the sentinel event system - notification for occupational risks (SENSOR): California, 1989-1991. Berkeley, CA: Department of Health Services, California Occupational Health Program.

CDC (Centers for Disease Control) [1988]. Guidelines for evaluating surveillance systems. MMWR 37(S-5):1-18.

Chipman JR, Kasdan ML, Camacho DG [1991]. Tendinitis of the upper extremity. In: Kasdan ML, ed. Occupational Hand and Upper Extremity Injuries and Diseases. Philadelphia, PA: Hanley & Belfus, Inc., pp. 403-421.

Corlett EN, Bishop RP [1976]. A technique for assessing postural discomfort. Ergonomics 19(2):175-182.

Curwin S, Stanish WD [1984]. Tendinitis: its etiology and treatment. Lexington, MA: D.C. Heath and Company.

DHHS [1989]. The international classification of diseases. 9th revision - clinical modification - third edition. Vol. 1 - Diseases/tabular list. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, Health Care Financing Administration, DHHS Publication No. (PHS) 89-1260.

Drury CG [1983]. Task analysis methods in industry. Appl Ergonomics 14(1)19-28.

Drury CG, Paramore B, Van Cott HP, Grey SM, Corlett EN [1987]. Task analysis. In: Salvendy G, ed. Handbook of human factors. New York, NY: John Wiley & Sons, pp. 370-401.

Feuerstein M [1992]. Workplace based prevention and management of upper extremity cumulative trauma disorders. Washington, DC: APA/NIOSH Conference Stress in the 90's: a Changing Workplace, November 19-22, 1992.

Flowerdew RE, Bode OB [1942]. Tenosynovitis in untrained farm workers. BMJ 2:367.

Franklin GM, Haug J, Heyer N, Checkoway H, Peck N [1991]. Occupational carpal tunnel syndrome in Washington State, 1984-1988. AJPH 81(6):741-746.

Frymoyer JW, Pope MH, Clemints JH, Wilder DG, MacPherson B, Ashikaga T [1983]. Risk factors in low back pain: an epidemiological survey. J Bone Joint Surg 65A:213-218.

Gamberale F [1972]. Perceived exertion, heart rate, oxygen uptake and blood lactate in different work operations. Ergonomics 15(5):545-554.

Haig AJ, Linton P, McIntosh M, Moneta L, Mead PB [1990]. Aggressive early medical management by a specialist in physical medicine and rehabilitation: effect on lost time due to injuries in hospital employees. J Occup Med 32:241-244.

Hales TR, Bertsche PK [1992]. Management of upper extremity cumulative trauma disorders. AAOHN 40:118-128.

Howard NJ [1937]. Peritendinitis crepitans: a muscle-effort syndrome. J Bone Joint Surg 19:447-459.

Howard NJ [1938]. A new concept of tenosynovitis and the pathology of physiologic effort. Am J Surg 42:723-730.

Kamon E, Kiser D, Pytel JL [1982]. Dynamic and static lifting capacity and muscular strength of steelmill workers. Am Ind Hyg Assoc J 43(11):853-857.

Kessler FB [1986]. Complications of the management of carpal tunnel syndrome. Hand Clinics 2:401-406.

Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sorensen F, Andersson G et al. [1987]. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl Ergonomics 18.3:233-237.

Lane C [1991]. Hand therapy of occupational upper extremity disorders. In: Kasdan ML, ed. Occupational Hand and Upper Extremity Injuries and Diseases. Philadelphia, PA: Hanley & Belfus, Inc., pp. 469-477.

Leavitt SS, Johnson TL, Beyer RD [1971]. The process of recovery: patterns in industrial back injuries. Part II - Predicting outcomes from early case data. Ind Med 40:7-15.

Lederman RJ, Calabrese LH [1986]. Overuse syndromes in instrumentalists. Med Probl Perform Art 1:7-11.

Lifshitz Y, Armstrong TJ [1986]. A design checklist for control and prediction of cumulative trauma disorder in intensive manual jobs. In: Proceedings of the Human Factors Society, 30th Annual Meeting, pp. 837-841.

Linton SJ, Kamwendo K [1989]. Risk factors in the psychosocial work environment for neck and shoulder pain in secretaries. JOM 31(7):609-613.

Lutz G, Hansford T [1987]. Cumulative trauma disorder controls: the ergonomics program at Ethicon, Inc. J Hand Surg 12A:863-866.

Mathiowetz V, Kashman N, Volland G, Weber K, Dowe M, Rogers S [1985]. Grip and pinch strength: normative data for adults. Arch Phys Med Rehabil 66(2):69-74.

Mayer TG, Gatchel RJ, Mayer H, et al. [1987]. A prospective two-year study of functional restoration in industrial low back injury: an objective assessment procedure. JAMA 258:1763-1767.

McKenzie F, Storment J, Van Hook P, Armstrong TJ [1985]. A program for control of repetitive trauma disorders associated with hand tool operations in a telecommunications manufacturing facility. Am Ind Hyg Assoc J 46(11):674-678.

Meister D [1985]. Behavioral analysis and measurement methods. New York, NY: John Wiley & Sons.

Moore JS [1992]. The muscle-tendon unit. Occupational Medicine: State of the Art Reviews 7:713-740.

Morganstern H, Keish M, Kraus J, Margolis W [1991]. A cross-sectional study of hand/wrist symptoms in female grocery checkers. Am J Ind Med 20:209-218.

NIOSH [1981]. Work practices guide for manual lifting. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 81-122.

NIOSH [1988]. National occupational exposure survey. Volume 1 - survey manual. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 88-106.

NIOSH [1990]. NIOSH Alert: request for assistance in preventing knee injuries and disorders in carpet layers. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 90-104.

NIOSH [1992a]. Health hazard evaluation report: U.S. West Communications, Phoenix, Arizona, Minneapolis, Minnesota, Denver, Colorado. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, HETA 89-299-2230.

NIOSH [1992b]. Health hazard evaluation report: Los Angeles Times, Los Angeles, California. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, HETA 90-013-2277.

Olson JE, Stravino VD [1972]. A review of cryotherapy. Physical Therapy 52:840-853.

OSHA [1990]. Ergonomics program management guidelines for meatpacking plants. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration, OSHA Publication No. 3123.

Pope MH, Andersson GBJ, Frymoyer JW, Chaffin DB [1991]. Occupational low back pain: assessment, treatment and prevention. St. Louis, MO: Mosby Year Book.

Putz-Anderson V [1988]. Cumulative trauma disorders: a manual for musculoskeletal diseases of the upper limbs. Philadelphia, PA: Taylor & Francis.

Putz-Anderson V and Waters T [1991]. Revisions in NIOSH guide to manual lifting. Paper presented at national conference entitled "A national strategy for occupational musculoskeletal injury prevention -- implementation issues and research needs." Ann Arbor, MI: University of Michigan.

Putz-Anderson V, Doyle G, Hales TR [1992]. Ergonomic analysis to characterize task constraint and repetitiveness as risk factors for musculoskeletal disorders in telecommunication office work. Scand J Work Environ Health 18(2):123-126.

Rempel DM, Harrison RJ, Barnhardt S [1992]. Work-related cumulative trauma disorders of the upper extremity. JAMA 267:838-842.

Rosa R, Wheeler DD, Warm JS, Colligan MJ [1985]. Extended workdays: effects on performance and ratings of fatigue and alertness. Behavior, Research Methods, Instruments & Computers 17(1):6-15.

Saito K [1987]. Prevention of the hand-arm vibration syndrome. Scand J Work Environ Health 13:301-304.

Silverstein BA, Fine LJ, Armstrong TJ [1986]. Hand wrist cumulative trauma disorders in industry. Br J Ind Med 43:779-784.

Silverstein BA, Armstrong TJ, Longmate A, Woody D [1988]. Can in-plant exercise control musculoskeletal symptoms? J Occup Med 30(12):922-927.

Simon HB [1991]. Current topics in medicine: sports medicine. In: Rubenstein & Federman, eds. Scientific American Medicine. New York, NY: Scientific American Inc., pp. 24-25.

Simon LS, Mills JA [1980]. Drug therapy: nonsteroidal antiinflammatory drugs (Parts 1 and 2). N Eng J Med 302:1179, 1237.

Snyder TB, Himmelstein J, Pransky G, Beavers JD [1991]. Business analysis in occupational health and safety consultations. JOM 33:1040-1045.

Thompson AR, Plewes LW, Shaw EG [1951]. Peritendinitis crepitans and simple tenosynovitis: a clinical study of 544 cases in industry. Br J Ind Med 8:150-160.

Thorsson O, Lilja B, Ahlgren L, Hemdal B, Westlin N [1985]. The effect of local cold application on intramuscular blood flow at rest and after running. Med and Sci Sports and Exer 17:710-713.

Thorson EP, Szabo RM [1989]. Tendinitis of the wrist and elbow. Occupational Medicine: State of the Art Reviews 7:713-740.

Waters TR, Putz-Anderson V, Garg A, Fine LJ [in press]. Revised NIOSH equation for the design and evaluation of manual lifting tasks. Ergonomics.

Wilson JR, Grey SM [1984]. Reach requirements and job attitudes at laser-scanner checkout systems. Ergonomics 27(12):1247-1266.

Yackzan L, Adams C, Francis K [1984]. The effects of ice massage on delayed muscle soreness. Am J of Sports Med 12:159-165.

EXAMPLES OF ERGONOMIC CHECKLISTS

Table 4. Michigan's Checklist for Upper Extremity Cumulative Trauma Disorders*

Risk Factors:	NO	YES
1. Physical Stress:		
1.1 Can the job be done without hand/wrist contact with sharp edges?	[ ]	[ ]
1.2 Is the tool operating without vibration?	[ ]	[ ]
1.3 Are the worker's hands exposed to temperature > 70° F?	[ ]	[ ]
1.4 Can the job be done without using gloves?	[ ]	[ ]
2. Force:		
2.1 Does the job require exerting less than 10 lbs of force?	[ ]	[ ]
2.2 Can the job be done without using finger pinch grip?	[ ]	[ ]
3. Posture:		
3.1 Can the job be done without flexion or extension of the wrist?	[ ]	[ ]
3.2 Can the tool be used without flexion or extension of the wrist?	[ ]	[ ]
3.3 Can the job be done without deviating the wrist side to side?	[ ]	[ ]
3.4 Can the tool be used without deviating the wrist side to side?	[ ]	[ ]
3.5 Can the worker be seated while performing the job?	[ ]	[ ]
3.6 Can the job be done without "clothes wringing" motion?	[ ]	[ ]
4. Workstation Hardware:		
4.1 Can the orientation of the work surface be adjusted?	[ ]	[ ]
4.2 Can the height of the work surface be adjusted?	[ ]	[ ]
4.3 Can the location of the tool be adjusted?	[ ]	[ ]
5. Repetitiveness:		
5.1 Is the cycle time longer than 30 seconds?	[ ]	[ ]
6. Tool Design:		
6.1 Is the thumb and finger slightly overlapped in a closed grip?	[ ]	[ ]
6.2 Is the span of the tool's handle between 5 and 7 cm?	[ ]	[ ]
6.3 Is the handle of the tool made from material other than metal?	[ ]	[ ]
6.4 Is the weight of the tool below 4 kg (note exceptions to the rule)?	[ ]	[ ]
6.5 Is the tool suspended?	[ ]	[ ]

["No" responses are indicative of conditions associated with the risk of CTDs.]

*Lifshitz, Y., and Armstrong, T. A design checklist for control and prediction of cumulative trauma disorders in hand intensive manual jobs. Proceedings of the 30th Annual Meeting of Human Factors Society, 837-841, 1986.

GENERAL JOB INFORMATION

STUDY ID: |__|__|__| [1-3]

FORM NUMBER: |0|1| [4-5]
FORM REVISION: |0|1| [6-7]

1. How long have you worked with your present employer? YEARS |__|__| MONTHS |__|__| [8-11]

2. What is your current JOB TITLE:________________ |__|__| [12-13]

3. How long have you worked in this job? YEARS |__|__| MONTHS |__|__| [14-17]

4. Select the most appropriate description of your JOB SITUATION:

   1 Full-time permanent employee
   2 Full-time temporary employee
   3 Part-time permanent employee
   4 Casual
   5 Other ________________ |__| [18]
   SPECIFY

5. Select the description that comes closest to your present WORK SHIFT:

   1 Rotating eight-hour shift
   2 Rotating twelve-hour shift
   3 Permanent day shift
   4 Permanent evening shift
   5 Permanent night shift
   6 Other________________ |__| [19]
   SPECIFY

6. How long have you worked the shift you circled above? YEARS |__|__| MONTHS |__|__| [20-23]

7. IF you work on a rotating shift, what ROTATION PATTERN do you follow?

EIGHT-HOUR SHIFT	TWELVE-HOUR SHIFT:
1 DAY to EVENING to NIGHT	4 DAY to NIGHT
2 NIGHT to EVENING to DAY	5 NIGHT to DAY
3 No set pattern	6 No set pattern

|__| [24]

8. How many times a week do you change shifts?

   1 0 times [I don't change]
   2 2 times
   3 More than 2 times
   4 On call
   5 Standby
   6 Non standard work week
   7 Other______________ |__| [25]
   SPECIFY

9. How many hours do you normally work per week in your job? |__|__| [26-27]

10. How many hours overtime do you work in your job in an average week? |__|__| [28-29]

11. How many hours per week do you work on any other job? |__|__| [30-31]
    [PLEASE MARK "|0|0|" IF NO OTHER JOB]

Ergonomics Checklist by Kellerman, van Wely, and Williams (1963).

A. DIMENSIONS

1. Has a tall man enough room?
2. Can a petite woman reach everything?
3. Is the work within normal reach of arms and legs?
4. Can the worker sit on a good chair? (height, seat, back)
5. Is an armrest necessary, and (if so) is it a good one? (Location, shape, position, material)
6. Is a footrest required, and (if so) is it a good one? (Height dimensions, shape, slope)
7. Is it possible to vary the working-posture?
8. Is there sufficient space for knees and feet?
9. Is the distance between eyes and work correct?
10. Is the work plane correct for standing work?

B. FORCES

1. Is static work avoided as far as possible?
2. Are vices, jigs, conveyor belts, etc., used wherever possible?
3. Where protracted loading of a muscle is unavoidable, is the muscular strength required less than 10% of the maximum?
4. Are technical sources of power employed where necessary?
5. Has the number of groups of muscles employed been reduced to the minimum with the aid of countersupport?
6. Are torques around the axis of the body avoided as far as possible?
7. Is the direction of motion as correct as possible in relation to the amount of force required?
8. Are loads lifted and carried correctly, and are they not too heavy?

Biomechanics Checklists

Following are two checklists which may assist you in applying Biomechanics to your tasks and machine design. You want a yes answer to each question.

Task Element Checklist

1. Is the element necessary?
2. Are all movements, holds, and delays necessary?
3. Is the back straight?
4. Is the back free from twisting?
5. Are elbows by the side of the body?
6. Are wrists straight?
7. Are movements natural and ballistic?
8. Is work area free of obstructions?
9. Are stop switches, controls, lock outs, and guards convenient and adequate?
10. Is the weight lifted less than 32.2-1.2 x the number of lifts per minute and is the weight carried less than 32 lbs.?

Machine Design Checklist

1. Is equipment operated with back erect, no twisting, supported if seated, foot rest if standing?
2. Are controls and materials near stomach and in sequence of use?
3. Can operator's movements be ballistic?
4. Can equipment be operated with straight wrists?
5. Are readouts and gages simple, in sequence, and do not require head movements?
6. Are handles and surfaces not applying pressure on small skin areas?
7. Are stop and off switches where operator will be?
8. Are guards easy to remove and replace without tools?
9. Does equipment require minimum tools which are displayed in order of use?
10. Is there accumulation of material before and after machine operation?

Inspection Checklist

Job ______________________________ Location ________________

- ☐ Twisting, "clothes-wringing" motions of the wrist.
- ☐ Working with a bent wrist.
- ☐ Vibrating tools.
- ☐ Poor handgrips on tools.
- ☐ Repetitive hand, arm and shoulder movements.
- ☐ Arms and elbows high or outstretched.
- ☐ Controls or materials beyond easy reach of the worker.
- ☐ Working with a bent neck.
- ☐ Working with a bent spine or leaning over excessively.
- ☐ Lifting, loading or unloading from improper heights.
- ☐ Excessive twisting or stretching of the back.
- ☐ Excessive pushing or pulling on loads.
- ☐ Excessive standing.
- ☐ Working in an immobile position for too long.
- ☐ Improper heights of work surfaces and chairs.

Evaluation form

ERGONOMIC JOB ANALYSIS ___/___ ___ _______ no. [ ]

Firm/workplace ______________________ Department ______________________

Job ______________________ Work site ______________________

____

Equipment, machines ____

Job description, work phases (1,2,3...) ____

____

____

____

____

Drawing of the work site and photograph

	Analyst's rating					Worker's assessment				Comments
1 Work space			3	4	5	++	+		--	
2 General physical activity			3	4	5	++	+		--	
3 Lifting			3	4	5	++	+		--	
4 Work postures and movements			3	4	5	++	+		--	
5 Accident risk			3	4	5	++	+		--	
6 Job content			3	4	5	++	+		--	
7 Job restrictiveness			3	4	5	++	+		--	
8 Worker communication			3	4	5	++	+		--	
9 Difficulty of decision making			3	4	5	++	+		--	
10 Repetitiveness of the work			3	4	5	++	+		--	
11 Attentiveness			3	4	5	++	+		--	
12 Lighting			3	4	5	++	+		--	
13 Thermal environment			3	4	5	++	+		--	
14 Noise			3	4	5	++	+		--	

Recommendations ____

____

____

1 Work space — Mark, if defect occur:

1 Horizontal work area ☐ 5 Seat ☐
2 Working height ☐ 6 Hand tools ☐
3 Viewing ☐ 7 Other equipment ☐
4 Leg space ☐

additional analyses

analyst's rating ☐ worker's assessment

2 General physical activity

analyst's rating ☐ worker's assessment

3 Lifting

lifting height ☐ normal ☐ low
weight of load ___ kg handhold distance ___ cm

number of loads lifted

lifting conditions

analyst's rating ☐ worker's assessment

4 Work postures and movements

	basic rating	duration (h/day)	rating corrected
neck-shoulders	☐	___	☐
elbow-wrist	☐	___	☐
back	☐	___	☐
hips-legs	☐	___	☐

analyst's rating ☐ worker's assessment

5 Accident risk

accident risk	accident severity
☐ small	☐ slight
☐ considerable	☐ minor
☐ great	☐ rather serious
☐ very great	☐ very serious

1 2 3 4 5 6 7 8 9 10 11 See the booklet for the corresponding numbers

analyst's rating ☐ worker's assessment

6 Job content

analyst's rating ☐ worker's assessment

7 Job restrictiveness

analyst's rating ☐ worker's assessment

8 Worker communication and personal contacts

analyst's rating ☐ worker's assessment

9 Decision making

analyst's rating ☐ worker's assessment

10 Repetitiveness of the work cycle length ___ min

analyst's rating ☐ worker's assessment

11 Attentiveness

observation period % of cycle length	attention demanded
☐ under 30	☐ superficial
☐ 30-60	☐ average
☐ 60-80	☐ rather great
☐ over 80	☐ very great

analyst's rating ☐ worker's assessment

12 Lighting

illumination intensity ___ lx, recommended value ___ lx, ___ %
glare ☐ no ☐ some ☐ much

analyst's rating ☐ worker's assessment

13 Thermal environment temperature measurements (°C)

average ___ °C
airflow rate m/s ___

	sitting	standing		
at head height	☐	☐	☐	☐
ankle level	☐	☐	☐	☐

analyst's rating ☐ worker's assessment

14 Noise

Estimated or measured
noise level ___ dB(A)

work demands
verbal communication ☐ concentration ☐

analyst's rating ☐ worker's assessment

SUPPLEMENTAL NOTES FOR METABOLIC CHECK LIST

Question

1. line/machine paced: The time to complete one unit is determined by the speed of an assembly line or by the speed of a machine. The worker has little or no control over the allowed time to complete a unit.
   leader paced: Work is performed by a team. One team member determines the pace of the entire team.
   standard paced: The worker must meet a daily production standard or quota but is able to work at his/her own pace with little outside influence.
   self paced: The worker sets his/her own pace. No formal standard or quota exists.

2. Does the worker have difficulty performing the job in the allotted cycle time?

   never - The worker is able to perform the job in the allotted cycle time for all cycles.
   sometimes - The worker is having difficulty performing the job in the allotted cycle time for some cycles, but not all cycles.
   usually - The worker is having difficulty performing the job in the allotted cycle time for most cycles and can only rest during break periods.

4. Does the worker walk faster than a normal pace?
   A "normal pace" is approximately 3 to 4 miles per hour. Discretion must be used to determine if the job requires the worker to walk fast or if the worker chooses to walk fast.

6. Does the worker bend or stoop below the knees repeatedly?
   never - The worker maintains an upright posture throughout the day.
   sometimes - The worker must bend down to reach below the knees 1 - 3 times per minute.
   usually - The worker must bend down to reach below the knees 4 or more times per minute.

7. never - The job function does not require the worker to wear a respirator or a complete protective suit under any circumstances.
   sometimes - The job function may require the worker to wear a respirator or a complete protective suit.
   usually - The worker must wear a respirator or a complete protective suit on a *regular or routine* basis.

5/11/90

JobNumber ____________________

BASIC JOB CHECK LIST
METABOLIC CHECK LIST

Note: When filling out this checklist, record what you observe on the day of this analysis.

1. Is the job cycle line/machine paced? leader paced? (work teams) standard paced? self paced?

	never	sometimes	usually	element
2. Does the worker have difficulty performing the job in the allotted (i.e. standard) cycle time?	o	√	√	
3. Does the worker appear out of breath?	o	√	*	
4. Does the worker walk faster than a normal pace?	o	√	√	____
5. Does the worker climb up or down more than 3 steps during the cycle?	o	√	√	____
6. Does the worker bend or stoop below the knees repeatedly?	o	√	*	____
7a. Is a respirator worn? (Note: This <u>does not</u> include dust masks, goggles, or welding shields. It <u>does</u> include any type of air-supplied respirator or any type of full or half-face respirators used to protect against toxic vapors or gases.)	o	*	*	____
b. Is a complete protective suit worn? (Note: This <u>does not</u> include hair protection or coveralls such as those used in welding areas. It <u>does</u> include all-enclosing impervious suits used to protect against toxic materials.)	o	*	*	____

Total Score = ____ ____ + ____ ____
(No. of *'s) (No. of √'s)

Comments:

/90

Table 1

EXAMPLES OF ERGONOMIC INTERVENTIONS

1. Repetitiveness

    a. Use mechanical aids
    b. Enlarge work content by adding more diverse activities
    c. Automate certain tasks
    d. Rotate workers
    e. Increase rest allowances
    f. Spread work uniformly across workshift
    g. Restructure jobs

2. Force/Mechanical Stress

    a. Decrease the weight of tools/containers and parts
    b. Increase the friction between handles and the hand
    c. Optimize size and shape of handles
    d. Improve mechanical advantage
    e. Select gloves to minimize effects on performance
    f. Balance hand-held tools and containers
    g. Use torque control devices
    h. Optimize pace
    i. Enlarge corners and edges
    j. Use pads and cushions

3. Posture

    a. Locate work to reduce awkward postures
    b. Alter position of tool
    c. Move the part closer to the worker
    d. Move the worker to reduce awkward postures
    e. Select tool design for work station

4. Vibration

    a. Select tools with minimum vibration
    b. Select process to minimize surface and edge finishing
    c. Use mechanical assists
    d. Use isolation for tools that operate above resonance point
    e. Provide damping for tools that operate at resonance point
    f. Adjust tool speed to avoid resonance

5. Psychosocial Stresses

a. Enlarge workers' task duties
b. Allow more worker control over pattern of work
c. Provide micro work pauses
d. Minimize paced work
e. Eliminate blind electronic monitoring

TABLE 2

SELECT STUDIES DEMONSTRATING EFFECTIVENESS OF ENGINEERING CONTROLS FOR REDUCING EXPOSURE TO ERGONOMIC RISK FACTORS

STUDY	TARGET POPULATION	PROBLEM/ RISK FACTOR	CONTROL MEASURE	EFFECT
Miller, Ransohoff and Tichauer [1971]	Surgeons (bayonet forceps)	Muscle fatigue during forceps use, frequent errors while passing instruments	Redesigned forceps (increase surface area)	Reduced muscle tension (determined by EMG, fewer passing errors)
Armstrong, Kreutzberg and Foulke [1982]	Poultry cutters (knives)	Excessive muscle force during poultry cutting tasks	Redesigned knife (reoriented blade, enlarged handle, provided strap for hand)	Reduced grip force during use, reduced forearm muscle fatigue
Knowlton and Gilbert [1983]	Carpenters (hammers)	Muscle fatigue, wrist deviation during hammering	Bent hammer handle, decreased handle diameter	Less strength decrement after use, reduced ulnar wrist deviation
Habes [1984]	Auto workers	Back fatigue during embossing tasks	Provided cut out in die (reduce reach distance)	Reduced back muscle fatigue as determined by EMG
Goel and Rim [1987]	Miners (pneumatic chippers)	Hand-arm vibration	Provided padded gloves	Reduced vibration transmitted to the hand by 23.5 - 45.5%
Wick [1987]	Machine operators in a sandal plant	Pinch grips, wrist deviation, high repetition rates, static loading of legs and back	Provided adjustable chair and bench-mounted armrests, angled press, provided parts bins	Reduced wrist deviation, compressive force on L5/S1 disc (from 85 to 13 lbs)
Little [1987]	Film notchers	Ulnar deviation, high repetition rates, pressure in the palm of the hand imposed by notching tool	Redesigned notching tool (extended, widened and bent handles, reduced squeezing force)	Reduced force from 12-15 to 10 lbs, eliminated ulnar wrist deviation, increased productivity by 15%
Johnson [1988]	Power hand tool users	Muscle fatigue, excessive grip force	Added vinyl sleeve and brace to handle	Reduced grip force as determined by EMG
Fellows and Freivalds [1989]	Gardeners (rakes)	Blisters, muscle fatigue	Provided foam cover for handle	Reduced muscle tension and fatigue buildup as determined by EMG
Andersson [1990]	Power hand tool users	Hand-arm vibration	Provided vibration damping handle	Reduced hand-transmitted vibration by 61-85%

STUDY	TARGET POPULATION	PROBLEM/ RISK FACTOR	CONTROL MEASURE	EFFECT
Miller, Ransohoff and Tichauer [1971]	Surgeons (bayonet forceps)	Muscle fatigue during forceps use, frequent errors while passing instruments	Redesigned forceps (increase surface area)	Reduced muscle tension (determined by EMG, fewer passing errors)
Radwin and Oh [1991]	Trigger-operated power hand tool users	Excessive hand exertion and muscle fatigue	Extended trigger	Reduced finger and palmar force during tool operation by 7%
Freudenthal et al. [1991]	Office workers	Static loading of back and shoulders during seated tasks	Provided desk with 10 degree incline, adjustable chair and table	Reduced moment of force at L5-S1 by 29%, at C7-T1 by 21%
Powers, Hedge and Martin [1992]	Office workers	Wrist deviation during typing tasks	Provided forearm supports and a negative slope keyboard support system	Reduced wrist extension
Erisman and Wick [1992]	Assembly workers	Pinch grips, wrist deviation	Provided new assembly fixture	Eliminated pinch grips, reduced wrist deviations by 65%, reduced cycle time by 50%
Luttmann and Jager [1992]	Weavers	Forearm muscle fatigue	Redesigned workstation (numerous changes)	Reduced fatigue build-up as indicated by EMG, improved quality of product

TABLE 3

SELECT STUDIES OF THE EFFECTIVENESS OF VARIOUS CONTROL STRATEGIES FOR REDUCING MUSCULOSKELETAL INJURIES

STUDY	TYPE OF WORK TASK	NUMBER OF WORKERS	METHOD OF INTERVENTION	SUMMARY OF RESULTS	ADDITIONAL COMMENTS
Jonsson [1988b]	Telephone assembly, manufacturing printed circuit cards, glass blowing, mining work	25 total workers studied	Job rotation	Job rotation in light duty tasks not as effective as in dynamic heavy duty tasks	Measured static load in trapezius muscle with EMG
Westgaard and Aaras [1984; 1985]	Production of cable forms	100 workers	Introduced adjustable workstations and fixtures, counterbalanced tools	Turnover decreased, musculoskeletal sick leave reduced by 2/3 over 8 year period; productivity increased	Positive effects of interventions verified by reductions in trapezius muscle EMG
Itani et al. [1979]	Photographic film rolling workers	124 total workers in two groups	Reduced work time, increased number of rest breaks	Reduction in cervicobrachial disorder and low back complaints; improved worker health	Post intervention productivity 86% of preintervention levels
Luopajarvi et al. [1982]	Food production packing tasks	200 workers	Redesigned packing machine	Decreases in neck, elbow, and wrist pain	Not all recommended job changes implemented; workers still complain
McKenzie et al. [1985]	Telecommunications equipment manufacturer	6600 employees	Redesigned handles on powered screwdrivers and wire wrapping guns; instituted plant-wide ergonomics training program	Incidence rate of repetitive trauma disorders decreased from 2.2 to .53 cases/200,000 work hours and lost days reduced from 1001 to 129 in three years	Data inadequate for rigorous statistical evaluation
Rigdon [Wall Street Journal 1992]	Bakery	630 employees	Formed union-management CTD committee; work station changes, tool modifications, improved work practices	CTS cases dropped from 34 to 13 in 4 years, lost days reduced from 731 to 8	Union advocated more equipment to reduce manual material handling
Lutz and Hansford [1987]	Manufacturer of sutures and wound closure products	>1000	Introduced adjustable work stations and fixtures, mechanical aids to reduce repetitive motions, job rotation	Reduced medical visits from 76 to 28 per month	Results based on two departments with 33 employees; company enthusiastic about exercise program

STUDY	TYPE OF WORK TASK	NUMBER OF WORKERS	METHOD OF INTERVENTION	SUMMARY OF RESULTS	ADDITIONAL COMMENTS
Jonsson [1988b]	Telephone assembly, manufacturing printed circuit cards, glass blowing, mining work	25 total workers studied	Job rotation	Job rotation in light duty tasks not as effective as in dynamic heavy duty tasks	Measured static load in trapezius muscle with EMG
Silverstein et al. [1987]	Investment casting plant	136 workers	Specific ergonomic changes not mentioned	No relationship between ergonomic changes and prevalence of hand-wrist CTDs	Ergonomic changes did not reduce the risk of studied jobs
Jorgensen et al. [1987]	Airline baggage loaders	6 males	Introduced a telescopic bin loading system	Local muscular load on the shoulders and low back reduced	Measured EMG of the trapezius and erector spinae muscles
Geras et al. [unpublished]	Rubber and plastic parts workers	87 plants of a national company	Introduced an ergonomics training and intervention program; added material handling equipment, work station modifications to eliminate postural stresses	Lost time at two plants reduced from 4.9 and 9.7/200,000 hours to .9 and 2.6, respectively over 4-year period	Key to success has been increased training, awareness of hazards and improved communication between management and workers
LaBar [1992]	Household products manufacturer	800 workers	Introduced adjustable workstations, improved the grips on hand tools, improved parts organization and work flow	Reduced injuries (particularly back by 50%)	Company also has a labor-management safety committee that investigates ergonomics-related complaints
Orgel et al. [1992]	Grocery store	23 employees	Redesigned checkstand to reduce reach distances; installed a height-adjustable keyboard; trained workers to adopt preferred work practices	Lower rate of self-reported neck, upper back, and shoulder discomfort; no change in arm, forearm, wrist discomfort	Study lacked a control group
Kilbom [1988]	Reviews intervention programs in various industries	14 studies		Concludes that job redesigns are most effective, but as the physical environment improves, work organization and psychosocial factors become more important	

STUDY	TYPE OF WORK TASK	NUMBER OF WORKERS	METHOD OF INTERVENTION	SUMMARY OF RESULTS	ADDITIONAL COMMENTS
Jonsson [1988b]	Telephone assembly, manufacturing printed circuit cards, glass blowing, mining work	25 total workers studied	Job rotation	Job rotation in light duty tasks not as effective as in dynamic heavy duty tasks	Measured static load in trapezius muscle with EMG
Echard et al. [1987]	Automobile manufacturer		Redesigned tools, fixtures, and work organization in assembly operations	Reduced long-term upper extremity and back disabilities; reduced CTS surgeries by 50%	
Snook et al. [1978]	Insurance company survey	200 surveys	Selection of workers; training in lifting technique; design of lifting tasks to fit worker capabilities	Selection and training not effective; matching job demands to worker capabilities can reduce injuries by 2/3	Authors also conclude that 1/3 of low back injuries will occur no matter what hazard control approach is used
Drury and Wick [1984]	Shoe manufacturer	6 work sites	Work station redesign	Reduced postural stress; increased productivity	Trunk and upper limbs most affected by changes

TABLE 4
SELECTED STUDIES DEMONSTRATING EFFECTIVENESS OF ERGONOMICS TRAINING

AUTHORS	TASK (INDUSTRY)	SAMPLE	STUDY DESIGN	MEASURES	RESULTS
Brown et al. [1992]	Varied (Municipal)	74 workers w/job back injury history	Before - After 6 wk. Back School Non-equivalent controls	Records study: Lost time, lost time cost, medical cost, total cost	Trained workers had sig. before-after gains on all measures; fewer injury reports than controls
Orgel et al. [1992]	Check-out (Grocery)	23 workers	Before - After; no controls Training was part of ergonomics program	Self-report of discomfort	Ergonomics program resulted in some decrease in medication requirements and recovery days
Liker et al. [1990]	Ergonomic job analysis (Varied)	147 OSH specialists	Before - After Lecture-based training	Knowledge and physical stress estimation skills	Substantial gains in knowledge but not skills; simplistic analysis models preferred
Dortch & Trombly [1990]	Assembly by hand (Electronics)	18 workers	Before - After Handouts vs. handouts + demonstrations vs. controls	Behavior observation	Trained groups had reduced traumatizing movements when compared with controls
Genaidy et al. [1989]	Lifting and carrying (Packaging)	21 M workers	Before - After w/controls 8 Physical training sessions	Psychophysical endurance, ratings of perceived exertion	Psychophysical endurance doubled after training; perceived exertion did not change
St-Vincent et al. [1989]	Lifting (Geriatric hospital)	32 orderlies	12-18 months After only 12h classroom training	Trained behavior observers using a behavior grid	Procedures from training rarely used in horizontal moves; more frequently used for vertical
Rosenfeld et al. [1989]	Varied (Pharmaceutical)	522 workers	Before - After Physical training vs. social activity	Self-report of perceived workload, efficiency, fatigue	Physical training group had higher perceived workload but lower fatigue post training
Liker et al. [1989]	Many tasks (Auto and air conditioning mfg.)	4 Plants: 2 U.S. 2 Japan	Before - After changes by ergonomics committee; no controls	Qualitative: Worksite observations Records review	Both training by experts (U.S.) and peer or supervisor training (Japan) contributed to completion of job redesigns
Geras et al. [unpublished]	Varied (Auto mfg.)	Unknown # plant leaders	Before - After Training course + proactive ergonomics program	Lost time incidence rates	Substantial reductions in incidence rates after program was initiated
Chaffin et al. [1986]	Lifting (Warehouse)	33 material handlers	Before - After 2 4-hour training sessions	Expert analysis of random video-taped lifts	Post-training lifts were better on 2 of 5 criteria
McKenzie et al. [1985]	Varied (Communications mfg.)	6,600 workers	Before - After Training for ergonomics task force professionals only as part of ergo. program	Repetitive motion incidence rates	Reduced incidence rates corresponded with program implementation
Smith & Smith [1984]	Supervision Textile mfg.	100 supervisors	After only; no controls	Self-reports of attitudes toward ergonomic activities	Substantial support for ergonomics activities

AUTHORS	TASK (INDUSTRY)	SAMPLE	STUDY DESIGN	MEASURES	RESULTS
Scholey [1983]	Lifting (Geriatric hospital)	4 F nurses	Before - After Handouts + psysio-feedback + demonstration + practice	Truncal stress (outcome) Task analysis Behavior observation	Training was effective for 3 nurses but not for a less experienced nurse in a more demanding ward
Dehlin et al. [1981]	Lifting (Geriatric hospital)	45 F with low back symptoms	Before - After Fitness training vs. lifting technique training vs. controls	Self-reports of perception of work, low-back insufficiency, and determination of physical work capacity	Negligible differences; fitness training resulted in greater perceived need for information and less perceived exertion
Snook et al. [1978]	Lifting (Varied)	192 surveys	After only Training vs. no training	Self-report of insurance reps on their most recent claim	No training effects on injury incidence
Rohmert & Laurig [1977]	Varied (Auto mfg.)	195 workers	Before - After 4-day training course; no controls	Written questionnaire	Increased correlation between course time devoted to topic and importance rank

REFERENCES

Andersson [1990]. Design and testing of a vibration attenuating handle. Int J Industr Ergonomics 6(2):119-126.

Armstrong TJ, Kreutzberg KL, Foulke JA [1982]. Laboratory evaluation of knife handles for thigh boning. Ann Arbor, MI: University of Michigan, NIOSH Procurement No. 81-2637.

Armstrong TJ, Radwin RG, Hansen DJ, Kennedy KW [1986]. Repetitive trauma disorders: job evaluation and design. Hum Factors 28(3):325-336.

Arndt R [1987]. Work pace, stress, and cumulative trauma disorders. J Hand Surg 12A:866-869.

Baldwin TT, Ford JK [1988]. Transfer of training: A review and directions for future research. Personnel Psychology 41:63-105.

Bergquist-Ullman M, Larsson U [1977]. Acute low back pain in industry: a controlled prospective study with special reference to therapy and confounding factors. Acta Orthopedica Scandinavia 170:1-117.

Blackburn JD, Sage JE [1992]. Safety training and employer liability. Technical & Skills Training 3(5):29-33.

Brown KC, Sirles AT, Hilyer JC, Thomas MJ [1992]. Cost-effectiveness of a back school intervention for municipal employees. Spine 17(10):1224-1228.

Cal/OSHA [1992]. Cal/OSHA's proposed ergonomics regulation -- section by section breakdown. State of California/Occupational Safety and Health Administration.

Campbell JP [1988]. Training design for performance improvement. In: Campbell JP, Campbell RJ & Associates, eds. Productivity in organizations: new perspectives from industrial and organizational psychology. San Francisco: Josey-Bass.

Chaffin D, Andersson GBJ [1991]. Occupational biomechanics. 2nd ed. New York, NY: Wiley.

Chaffin DB, Gallay LS, Woolley CB, Kuciemba SR [1986]. An evaluation of the effect of a training program on worker lifting postures. Int J Industr Ergonomics 1:127-136.

Cole HP, Moss J, Gohs FX, Lacefield WE, Barfield BJ, Blyth DK [1984]. Measuring learning in continuing education for engineers and scientists. Phoenix, AZ: Oryx.

Dehlin O, Berg S, Andersson GBJ, Grimby G [1981]. Effect of physical training and ergonomic counselling on the psychological perception of work and on the subjective assessment of low-back insufficiency. Scand J Rehabil Med 13:1-9.

Dortch HL, Trombly CA [1990]. The effects of education on hand use with industrial workers in repetitive jobs. Amer J Occup Ther 44:777-782.

Drury CG, Wick J [1984]. Ergonomic applications in the shoe industry. In: Proceedings of the international conference on occupational ergonomics, pp. 489-93.

Eastman Kodak Company [1983]. Ergonomic design for people at work. Vol. 1. New York, NY: Van Nostrand Reinhold Company, Inc.

Eastman Kodak Company [1986]. Ergonomic design for people at work. Vol. 2. New York, NY: Van Nostrand Reinhold Company, Inc.

Echard M, Smolenski S, Zamiska M [1987]. Ergonomic considerations: engineering controls at Volkswagen of America. In: Ergonomic interventions to prevent musculoskeletal injuries in industry. Industrial Hygiene Science Series, ACGIH, Lewis Publishers, pp 117-31.

Erisman J, Wick J [1992]. Ergonomic and productivity improvements in an assembly clamping fixture. In: Kumar S, ed. Advances in industrial ergonomics and safety IV. Philadelphia, PA: Taylor & Francis, pp. 463-468.

Fellows GL, Freivalds A [1989]. The use of force sensing resistors in ergonomic tool design. In: Proceedings of the Human Factors Society 33rd Annual Meeting, pp. 713-717.

Fendrich DW, Healy AF, Meiskey L, Crutcher RJ, Litte W, Borne LE [1988]. Skill maintenance: literature review and theoretical analysis (AFHRL-TP-87-73). Brooks AFB, TX: Air Force Human Resource Laboratory.

Freudenthal A, van Riel MPJM, Molenbroek JFM, Snijders CJ [1991]. The effect on sitting posture of a desk with a ten-degree inclination using an adjustable chair and table. Appl Ergonomics 22(5):329-336.

Gagne RM, Briggs LJ [1979]. Principles of instructional design. 2nd ed. New York, NY: Holt, Rinehart & Winston.

Genaidy AM, Mital A, Bafna KM [1989]. An endurance training programme for frequent manual carrying tasks. Ergonomics 32:149-155.

Geras DT, Pepper CD, Rodgers SH [1988]. An integrated ergonomics program at the Goodyear Tire & Rubber Company. Unpublished.

Glover JR [1976]. Prevention of back pain. In: Jayson M, ed. The lumbar spine and back pain. New York, NY: Grune and Stratton.

Goel VK, Rim K [1987]. Role of gloves in reducing vibration: an analysis for pneumatic chipping hammer. Am Ind Hyg Assoc J 48(1):9-14.

Goldstein IL [1975]. Training. In: Margolis BL, Kroes WH, ed. The human side of accident prevention. Springfield, IL: Thomas.

Grandjean E [1988]. Fitting the task to the man: a textbook of occupational ergonomics. 4th ed. London, UK: Taylor and Francis.

Habes DJ [1984]. Use of EMG in a kinesiological study in industry. Appl Ergonomics 15(4):297-301.

Itani T, Onishi K, Sakai K, Shindo H [1979]. Occupational hazard of female film rolling workers and effects of improved working conditions. Arh hig rada toksikol 30:1243-1251.

Johnson SL [1988]. Evaluation of powered screwdriver design characteristics. Hum Factors 30(1):61-69.

Jonsson B [1988a]. The static load component in muscle work. Eur J Appl Physiol 57:305-310.

Jonsson B [1988b]. Electromyographic studies of job rotation. Scand J Work Environ Health 14(1):108-09.

Jorgensen K, Jensen B, Stokholm J [1987]. Postural strain and discomfort during loading and unloading flights: an ergonomic study. In: Asfour SS, ed. Trends in ergonomics/human factors IV. North Holland: Elsevier Science Publishers B.V., pp. 663-673.

Keyserling WM, Herrin GD, Chaffin DB [1980]. Isometric strength testing as a means of controlling medical incidents on strenuous jobs. JOM 22(5):332-36.

Keyserling WM, Herrin GD, Chaffin DB, Armstrong TJ, Foss ML [1978]. Establishing an industrial strength testing program. Am Ind Hyg Assoc J 41(10):730-36.

Kilbom A [1988]. Intervention programmes for work-related neck and upper limb disorders: strategies and evaluation. Ergonomics 31(5):735-47.

Knowlton RG, Gilbert JC [1983]. Ulnar deviation and short-term strength reductions as affected by a curve-handled ripping hammer and a conventional claw hammer. Ergonomics 26(2):173-179.

Komaki J, Barwick KD, Scott LR [1980]. Effect of training and feedback: Component analysis of a behavioral safety program. J Appl Psychol 65:261-270.

Konz S [1979]. Work design. Columbus, OH: Grid Publishing Co.

Kyllonen PC, Alluisi EA [1987]. Learning and forgetting facts and skills. In: Salvendy G, ed. Handbook of Human Factors. New York, NY: Wiley.

LaBar G [1992]. A battle plan for back injury prevention. Occupational Hazards, 29-33.

Liker JK, Evans SM, Ulin S [1990]. The strengths and limitations of lecture-based training in the acquisition of ergonomics knowledge and skill. Int J Industr Ergonomics 5:147-159.

Liker JK, Nagamachi M, Lifshitz YR [1989]. A comparative analysis of participatory ergonomics programs in U.S. and Japan manufacturing plants. Int J Industr Ergonomics 3:185-199.

Little RM [1987]. Redesign of a hand tool: a case study. Semin Occup Med 2(1):71-72.

Luopajarvi T, Kuorinka I, Kukkonen R [1982]. The effects of ergonomic measures on the health of the neck and upper extremities of assembly-line packers - a four year follow-up study. In: Noro, ed. Tokyo, Japan: Proceedings of the 8th Congress of the International Ergonomics Association, pp. 160-161.

Luttmann A, Jager M [1992]. Reduction in muscular strain by work design: electromyographical field studies in a weaving mill. In: Kumar S, ed. Advances in industrial ergonomics and safety IV. Philadelphia, PA: Taylor & Francis, pp. 553-560.

Lutz G, Hansford T [1987]. Cumulative trauma disorder controls: The ergonomics program at Ethicon, Inc. J Hand Surg 12A(5 Part 2): 863-66.

McKenzie F, Storment J, Van Hook P, Armstrong TJ [1985]. A program for control of repetitive trauma disorders associated with hand tool operations in a telecommunications manufacturing facility. Am Ind Hyg Assoc J 46(11):674-78.

Miller M, Ransohoff J, Tichauer ER [1971]. Ergonomic evaluation of a redesigned surgical instrument. Appl Ergonomics 2(4):194-197.

Mital A, Kilbom A [1992]. Design, selection and use of hand tools to alleviate trauma to the upper extremities: Part II - The scientific basis (knowledge base for the guide). Int J Industr Ergonomics 10:7-21.

Moran JB, Ronk RM [1987]. Personal protective equipment. In: Salvendy G, ed. Handbook of human factors. New York, NY: John Wiley & Sons, pp. 876-894.

NIOSH [1981]. Work practices guide for manual lifting. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 81-122.

NOHSC [1992]. Guidance note for the prevention of occupational overuse syndrome in the manufacturing industry. Commonwealth of Australia: National Occupational Health and Safety Commission.

Orgel DL, Milliron MJ, Frederick LJ [1992]. Musculoskeletal discomfort in grocery express checkstand workers: an ergonomic intervention study. JOM 34(8):815-18.

OSHA [1990]. Ergonomics program management guidelines for meatpacking plants. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration, OSHA Publication No. 3123.

OSHA [1992]. Training requirements in OSHA standards and training guidelines. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration, OSHA Publication No. 2254 (revised).

Powers JR, Hedge A, Martin MG [1992]. Effects of full motion forearm supports and a negative slope keyboard system on hand-wrist posture while keyboarding. Atlanta, GA: Proceedings of the Human Factors Society 36th Annual Meeting, pp. 796-800.

Putz-Anderson V [1988]. Cumulative trauma disorders: a manual for musculoskeletal diseases of the upper limb. Philadelphia, PA: Taylor & Francis. Submitted with NIOSH comments to OSHA dated 2/1/93.

Putz-Anderson V, Galinsky T [1993]. Psychophysically determined work durations for limiting shoulder girdle fatigue from elevated manual work. Int J Ind Ergonomics 11:19-28.

Radwin RG, Oh S [1991]. Handle and trigger size effects on power tool operation. In: Proceedings of the Human Factors Society 35th Annual Meeting, pp. 843-847.

Rigdon JE [1992]. The wrist watch: how a plant handles occupational hazard with common sense. The Wall Street Journal, 9/28/92.

Rodgers SH [1988]. Job evaluation in worker fitness determination. In: Occupational Medicine: State of the Art Reviews. Philadelphia, PA: Hanley & Belfus, Inc.

Rohmert W, Laurig W [1977]. Increasing awareness of ergonomics by in-company courses -- a case study. Appl Ergonomics 8:19-21.

Rosenfeld O, Tenenbaum G, Ruskin H, Halfon S-T [1989]. The effect of physical training on objective and subjective measures of productivity and efficiency in industry. Ergonomics 32:1019-1028.

Rothstein MA [1984]. Medical screening of workers. Washington, DC: Bureau of National Affairs.

Rubinsky S, Smith NE [1971]. Evaluation of accident simulation as a technique for teaching safety procedures in the use of small power tools. Washington, D.C.: U.S. Govt. Printing Office, DHEW Publication (HSM) 72-10000.

Sanders MS, McCormick EJ, eds. [1982]. Human factors in engineering and design. Sixth edition. New York, NY: McGraw-Hill.

Scholey M [1983]. Back stress: the effects of training nurses to lift patients in a clinical situation. Int J Nursing Studies 20:1-13.

Silverstein B, Fine L, Stetson D [1987]. Hand-wrist disorders among investment casting plant workers. J Hand Surg 12A(5):Part 2:838-44.

Smith BJ, Delahaye BL [1987]. How to be an effective trainer (2nd ed.). New York: Wiley.

Smith LA, Smith JL [1984]. Observations on in-house ergonomics training for first-line supervisors. Appl Ergonomics 15:11-14.

Snook SH, Campanelli RA, Hart JW [1978]. A study of three preventive approaches to low back injury. JOM 20:478-481.

St-Vincent M, Tellier C, Lortie M [1989]. Training in handling: an evaluative study. Ergonomics 32:191-210.

Swanson NG, Sauter SL, Chapman LJ [1989]. The design of rest breaks for video display terminal work: a review of the relevant literature. In: Mital A, ed. Advances in industrial ergonomics and safety I.

Tichauer ER [1991]. Ergonomics. In: Clayton and Clayton, eds. Patty's Industrial Hygiene and Toxicology. 4th rev. ed. Vol. 1B, General Principles. New York, NY: Wiley.

Van Cott H, Kincaid R [1973]. Human engineering guide to equipment design. Washington, DC: Superintendent of Documents, U.S. Government Printing Office.

Vayrynen S, Kononen U [1991]. Short and long-term effects of a training programme on work postures in rehabilitees: a pilot study of loggers suffering from back troubles. Inter J Industr Ergonomics 7:103-110.

Vaught C, Brnich MJ, Kellner HJ [1988]. Effect of training strategy on self contained self rescuer donning performance. Mine Safety Education and Training Seminar, Bureau of Mines Information Circular. U.S. Department of the Interior, Report IC 9185, pp. 2-14.

Waters TR [1991]. Strategies for assessing multi-task manual lifting jobs. In: Proceedings of the Human Factors Society 35th Annual Meeting, pp. 809-813.

Westgaard RH, Aaras A [1984]. Postural muscle strain as a causal factor in the development of musculo-skeletal illnesses. Appl Ergonomics 15(3):162-74.

Westgaard RH, Aaras A [1985]. The effect of improved workplace design on the development of work-related musculo-skeletal illnesses. Appl Ergonomics 16(2):91-97.

Wick JL [1987]. Workplace design changes to reduce repetitive motion injuries in an assembly task: a case study. Semin in Occup Med 2(1):75-78.

Woodson WE [1981]. Human factors design handbook. New York, NY: McGraw-Hill.

Cumulative trauma disorders: A manual for musculoskeletal diseases of the upper limbs

Edited by
Vern Putz-Anderson

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Contents

Abstract

This manual was developed to define cumulative trauma disorders (CTDs) in the workplace, to enable non-medical personnel to recognize them, and to present strategies for preventing their occurrence. Emphasis is placed on CTDs of the upper extremities.

Part I of this manual defines the cumulative trauma category of musculoskeletal disorders. Information is provided on the structures of the hand and arm to help identify the symptoms and location of the disorders. Descriptions of some of the common types of CTDs are also provided along with examples of jobs in which CTDs may occur.

Part II presents methods for determining how many workers at a worksite have CTDs or have some early symptoms of CTDs. Extensive information on conducting an ergonomic job analysis is also provided. Information from such a job analysis is useful for identifying work conditions and tools that may cause or contribute to CTDs.

Part III focuses on two strategies used to control or prevent the occurrence of CTDs: *Instituting Personnel-Focused Practices* and *Redesigning Tools, Work Stations and Jobs*. The merits of each strategy are discussed. Combinations of elements of each strategy are frequently used in workplaces where prevention programs for CTDs have been implemented. Guidelines for ergonomic redesign are also provided along with a list of references for further information on ergonomics.

The Appendices include specialized material designed to supplement information contained in the body of the manual. Appendix A includes a glossary of terms and a series of illustrations to define the positions and movements of the body. Appendix B provides an introduction to the diagnostic process used by the medical profession to identify CTDs and a summary of medical procedures used to treat them. Appendix C defines some common epidemiological terms and describes statistical procedures for evaluating the prevalence, incidence, and severity of CTDs. In addition, a series of case histories are provided to illustrate the frequency and costs associated with CTDs among specific work populations.

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A review of physical exercises recommended for VDT operators

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This paper presents an evaluation of exercises that have been recommended for the prevention of musculoskeletal discomfort among VDT/office workers. 127 individual exercises were analysed for their suitability for performance in VDT workplaces. Additionally, each exercise was judged in terms of its safety and its compliance with principles of physiotherapy. Results showed that, in the majority of cases, the prepared instructions for the exercises were satisfactory and the exercises could be readily performed at the workstation. However, over a third of the exercises were conspicuous and potentially embarrassing to perform, and half would significantly disrupt the work routine. Additionally, a number of the exercises posed potential safety hazards, exacerbated biomechanical stresses common to VDT work, or were contraindicated for persons with certain health problems. These findings suggest a need for greater attention to both the practical and the therapeutic aspects of exercises promoted for VDT users.

Keywords: Exercise; office work; musculoskeletal discomfort

Introduction

Widespread study of video display terminal (VDT) users has raised concerns regarding the potential for musculoskeletal disorders among these individuals. In a review of the literature[1], the World Health Organization found that "... musculoskeletal discomfort was commonplace during work with VDTs ...," and that "injury from repeated stress to the musculoskeletal system is possible". In addition to the health implications, it is likely that musculoskeletal discomfort in VDT work is associated with performance impairments[2,3].

A review of current literature suggests that the primary emphasis for reducing musculoskeletal strain in VDT work has been on improving the workstation/environment by applying well-established ergonomic principles[4–7]. However, Winkel[8] suggests that ergonomically designed workstations are an incomplete prescription for preventing musculoskeletal discomfort in VDT work because they do not correct for a major contributory factor, namely, constrained postures. Constrained sedentary postures during VDT work may create static loading leading to muscle fatigue, impediment of circulation in the lower extremities, and stresses on joints, chronically stretched muscles and other tissues.

Winkel's contention that ergonomically designed workstations are an incomplete prescription for preventing musculoskeletal discomfort is supported by several studies showing that optimal workstation design does not eliminate the accumulation of musculoskeletal discomfort in VDT work[9,10]. What is needed, according to Winkel, is more dynamic activity to relieve the stresses of sedentary work[8].

This type of thinking no doubt underlies the proliferation of exercise programmes designed to reduce musculoskeletal discomfort arising from VDT work. However, there has been insufficient study of these exercise programmes, in the context of VDT/office work, to ascertain their effectiveness.

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An effective office exercise programme should satisfy two criteria. First, the exercises must be 'usable' (ie, they must be designed to maximize VDT users' ability and motivation to perform them). Second, the exercises must be sound from a physiotherapeutic/safety perspective (ie, they must effectively combat the stresses of VDT work, and performance of the exercises must not pose added safety or health risks). The purpose of this paper is not to advocate the substitution of exercises for job redesign (eg, changes in work routines which result in increased physical activity). Exercises should be regarded as a complement to, not a substitute for, improving the design of jobs to relieve the musculoskeletal stresses of VDT work.

In the present paper, we review exercises proposed for VDT users with regard to the usability and physiotherapeutic/safety criteria. For the usability assessment, it was assumed that exercises which are easy to learn, do not call undue attention to the individual, and can be easily integrated into the work routine, would be most readily utilized by VDT users. Assessments regarding physiotherapeutic value were restricted to judgements regarding potential safety or health risks associated with performance of a particular exercise because, unlike the apparent benefits of these exercises, potential risks have not been addressed.

Ultimately, the suitability of any set of exercises for office workers can be firmly established only through empirical study. The rationale behind the present review is to provide some basis for selection of exercises until empirical data emerge on their effectiveness.

Method

Identification of exercises for review

A total of 14 exercise programmes for VDT users and office workers were identified in the literature:

1 Austin[11]
2 Australian National University[12]
3 Australian Occupational Health and Safety Unit[13]
4 Dahl[14]
5 Emanuel and Glonek[15]
6 Gore and Tasker[16]
7 Joyce and Peterson[17–19]
8 Krames Communication[20,21]
9 Lacey[22]
10 Lee and Humphrey[23]
11 Lee and Waikar[24]
12 *Los Angeles Times*[25]
13 Pragier[26]
14 Sauter *et al*[1]

Two of the programmes[15,23] were designed for microscope operators. Because both microscopy and VDT work involve sedentary work and static postures of the upper extremities and neck/shoulder region, it was presumed that the types of musculoskeletal stresses experienced would be similar.

Of the 14 exercise programmes identified, only 12 were actually evaluated. The exercise programme of Lee and Humphrey[23] was not evaluated since it is identical to that of Emanuel and Glonek[15], except for the duration of the exercises. The exercises of the Australian Occupational Safety and Health Unit[13] were general relaxation exercises which did not target specific muscle groups.

Three sources[16–21] offered multiple exercise programmes. Gore and Tasker[16] offered 45 distinct exercises, organized into five separate exercise programmes (A–E). The programmes were virtually identical in terms of the musculoskeletal structures targeted. Therefore, we selected only programme A for analysis. The Joyce Institute[17–19] has three exercise programmes whose contents overlap. Only the unique exercises in these programmes were reviewed. The same procedure was used for the review of the two programmes by Krames Communications[20,21]. Similarly, because the majority of the Lee and Waikar[24] exercises were identical to those of Emanuel and Glonek[15], only the Lee and Waikar exercises which did not duplicate those of Emanuel and Glonek were included in the analysis.

Exercises which did not target specific musculoskeletal structures (ie, general relaxation exercises or eye exercises) were not included in the analysis. In all, 127 separate exercises were evaluated.

Evaluation procedure Table 1 lists each of the exercises analysed, the source, the exercise instructions, and a listing of the primary muscle groups and structures recruited. (The exercise instructions provided in Table 1 were abbreviated to economize on space. Most instructions included illustrations of a model performing the exercise. The analysis of the exercises was based on the original instructions and illustrations.)

The exercises were classified according to the body part targeted: (1) neck; (2) shoulder; (3) elbow/lower arm; (4) lower back/hip; and (5) knee/lower leg. Many exercises affected muscles from more than one body part. Each of these exercises was categorized under the body part primarily affected.

After classification, each exercise was analysed along a number of dimensions which potentially influenced its usability and physiotherapeutic value. The procedures for these assessments are described below.

Usability assessment

Each exercise was evaluated along five dimensions reflecting the presumed willingness and ability of VDT users to perform them at work. These dimensions were: (1) specificity of instructions; (2) location most suitable for performance; (3) conspicuousness; (4) time requirement/disruption of the work task; and (5) ease of learning/performance. The operational definitions and rating factors used for each of the evaluation end-points are as follows.

Specificity of instructions This dimension refers to the ease with which the instructions can be understood and followed. Three rating categories were utilized: good, fair or poor.

Location most suitable for performance Because the exercises vary in their time and space requirements, not

Table 1. Panel A. Neck Exercises.

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
1	Australian National University	Exercise 2	1) Stand as tall as possible, then 2) relax and go loose like a rag doll. (10 to 20 times).	Lower cervical and thoracic extensors, neck flexors (phase I only)	Upper cervical extensors, anterior ligaments of the lower cervical and upper thoracic spine (phase I), cervical and thoracic extensors, scapular adductors, elevators and upward rotators, posterior ligaments of the cervical and thoracic spine (phase II)	fair	work area	highly	mini	simple	a b c d 1 3
2	Sauter	Head Nods	Nod head (not entire neck) in "yes" motion.		Upper cervical extensor muscles, posterior ligaments of the cervical spine and facet joints	good	chair	somewhat	micro	simple	a b c 1 3
3	Gore and Tasker	The Pigeon	Standing or sitting, keep eyes looking forward. Without dropping head, pull face in to make double chin. Hold for count of 6. Repeat 10 times.	Lower cervical, thoracic and lumbar extensors, neck flexors	Upper cervical extensors, anterior ligaments of the lower cervical and upper thoracic spine	good	chair	no	mini	simple	
4	Krames Comm	Neck Glide	1) Glide head back, as far as it will go. Keeping head and ears level. 2) Now glide head forward. Repeat 3 times.	Phase I: Lower cervical, thoracic and lumbar extensors, neck flexors Phase II: Upper cervical extensors and neck flexors	Phase I: Anterior ligaments of the lower cervical and thoracic spine, upper cervical extensors *Phase II: Posterior ligaments* of the lower cervical and thoracic spine, lower cervical and thoracic extensors	good	chair	no	micro	simple	
5	LA Times	Dorsal Glides (Turkey)	Sit up straight and pull shoulders back. Slide head straight back on neck, keeping face pointed forward (Turkey Position). Isolate movement to head and neck. Repeat slowly 5 times.	Lower cervical, thoracic and lumbar extensors, scapular adductors, elevators and upward rotators, neck flexors	Anterior ligaments of the lower cervical and thoracic spine, upper cervical extensors	good	chair	no	micro	simple	
6	Joyce & Peterson	Cable Stretch	Sit relaxed, with feet flat on floor. Imagine a cable attached to the top of the head pulling you up. Hold for count of 3; relax. Repeat 3 times.	Lower cervical, thoracic and lumbar extensors, neck flexors	Anterior ligaments of the lower cervical and thoracic spine, upper cervical extensors	good	chair	no	micro	simple	
7	Pragler	Exercise a-1	Tuck the chin in, shoulders back and "sit tall". Hold the position for a count of 3; relax.	Lower cervical, thoracic and lumbar flexors/extensors, scapular adductors, elevators and upward rotators, neck flexors	Anterior ligaments of the lower cervical and thoracic spine, upper cervical extensors	good	chair	no	micro	simple	
8	Emanuel and Glonek	Neck Rotations	Rotate head and neck 3 times clockwise and 3 times counterclockwise.		Anterior and posterior cervical and thoracic rotators, neck upper back extensors and flexors, scapular elevators, anterior, lateral and posterior ligaments of the cervical and thoracic spine	fair	chair	somewhat	micro	simple	a b c 1 3 4

The exercise instructions have been abbreviated to economize on space. Most instructions included illustrations of a model performing the exercise. The analysis of the exercises was based on the original instructions and illustrations.

Key

1 Exercise reproduces physical stresses of VDT work
2 Exercise poses one or more safety hazards
3 Exercise stretches already overstretched structures
4 Exercise places additional loads on lumbar and/or thoracic discs

a Acute neck pain
b Degenerative disc disease
c Moderate to severe osteoporosis
d Acute lower back pain
e Second and third trimesters of pregnancy
f Acute inflammatory or arthritic conditions of the shoulder
i Acute inflammatory or arthritic conditions of the elbow/forearm complex
j Hand/wrist disorders, such as carpal tunnel syndrome
k Acute lateral epicondylitis
l Spinal stenosis
m Arthritic conditions of the hips and/or knees

Table 1. Panel A. Neck Exercises (cont.)

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
9	Australian National University	Exercise 5	Tuck chin in. Circle head in one direction, then in other. Repeat 10-15 times.	Cervical and thoracic flexors, sidebenders, rotators, extensors	Anterior and posterior cervical and thoracic rotators, neck/upper back flexors and extensors, scapular elevators, anterior, lateral and posterior ligaments of the cervical and thoracic spine	fair	chair	somewhat	mini	simple	a b c 1 3 4
10	Dahl	Unnamed	Rotate head to one side, then to the front, and to other side.	Cervical and thoracic rotators, neck flexors	Cervical and thoracic rotators, posterior and lateral ligaments of the cervical and thoracic spine and facet joints	*	chair	somewhat	micro	simple	a b c
11	Sauter	Head Turns	Close eyes and very slowly turn head from shoulder to shoulder (with head positioned upright).	Cervical and thoracic rotators, neck flexors	Cervical and thoracic rotators, posterior and lateral ligaments of the cervical and thoracic spine and facet joints	good	chair	somewhat	micro	simple	a b c
12	Krames Comm.	Head and Neck	Turn head slowly from one side to the other, holding each turn for a count of 3. Repeat 5-10 times.	Cervical and thoracic rotators, neck flexors	Cervical and thoracic rotators, posterior and lateral ligaments of the cervical and thoracic spine and facet joints	good	chair	somewhat	mini	simple	a b c
13	LA Times	Turkey with Rotation	Hold turkey position (see exercise 5) and slowly turn head to point of stretch sensation, first left, then right 3-5 times.	Cervical and thoracic rotators, neck flexors	Cervical and thoracic rotators, posterior and lateral ligaments of the cervical and thoracic spine and facet joints	fair	chair	somewhat	micro	simple	a b c
14	Gore and Tasker	Headrest	Sitting, lock fingers behind head, drop chin to chest. Slowly turn head to right and hold for count of 10. Relax. Repeat to left. Do 3 times on each side.		Upper thoracic and cervical extensors and rotators, posterior and lateral ligaments of thoracic cervical spine and facet joints	good	chair	somewhat	mini	simple	a b c 1 3 4 Alternative exercise to stretch the upper cervical muscles should be chosen that does not produce extreme flexion and rotation of lower cervical and upper thoracic spine.
15	Joyce & Peterson	Neck/Head	Slowly tip head from side to side 3 times. Bring head to upright, then turn it and look over shoulder 3 times to each side. Drop chin to chest, then raise it as far as possible 3 times.	Cervical and thoracic rotators, anterior and posterior cervical and thoracic rotators, neck flexors and extensors	Upper thoracic and cervical extensors, lateral, anterior and posterior ligaments of the thoracic and cervical spine and facet joints, cervical flexors, neck side benders, scapular elevators, anterior and posterior cervical and thoracic rotators	good	chair	somewhat	mini	simple	a b c 1 3 4
16	Austin	Neck	Let head drop slowly to left, then to right. Slowly drop chin to chest, then raise chin as high as possible. Turn head all the way to left, return to normal, then turn all the way right. Return to normal position.	Anterior and posterior cervical and thoracic rotators, neck flexors and extensors	Upper thoracic and cervical extensors, lateral, anterior and posterior ligaments of the thoracic and cervical spine and facet joints, cervical flexors, neck side benders, scapular elevators, anterior and posterior cervical and thoracic rotators	good	chair	somewhat	micro	simple	a b c 1 3 4

*As the Dahl exercises were translated from Danish to English for the authors, the specificity of the instructions was not evaluated

Key

1 Exercise reproduces physical stresses of VDT work
2 Exercise poses one or more safety hazards
3 Exercise stretches already overstretched structures
4 Exercise places additional loads on lumbar and/or thoracic discs

a Acute neck pain
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i Acute inflammatory or arthritic conditions of the elbow/forearm complex
j Hand/wrist disorders, such as carpal tunnel syndrome
k Acute lateral epicondylitis
l Spinal stenosis
m Arthritic conditions of the hips and/or knees

Table 1. Panel A. Neck Exercises (cont.)

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
17	Australian National University	Exercise 4	Place one hand on opposite shoulder. Pull shoulder down while bending head toward other shoulder. Repeat on other side. Repeat 5-10 times.		Neck side benders, scapular elevators, lateral ligaments of the upper thoracic and cervical spine and facet joints	fair	chair	somewhat	mini	simple	a b c 3 4 Avoid rapid stretching. May produce moderate loading on cervical discs if performed in forward, flexed head posture.
18	Gore and Tasker	Tension Neck	Standing, place left hand on back of neck. Point left elbow to ceiling and keep there. Drop chin on chest and turn head to right without lifting chin. Tilt right ear to right and hold for count of 10. Relax. Repeat with right hand, turning head to left. Do 3 times each side.		Neck side benders, scapular elevators, posterior and lateral ligaments of the upper and cervical spine and facet joints	fair	work area	highly	mini	simple	a b c 3 4 Avoid rapid stretching.
19	LA Times	Upper Trapezius Stretch	Grasp seat or leg of chair with right hand to pull shoulder down slightly. Lean head to left until stretch is felt on right side of neck. Lean body to left to increase stretch. Hold 15 seconds. Repeat on other side.		Neck side benders, scapular elevators	good	chair	somewhat	mini	simple	a b c 4 Avoid rapid stretching.
20	LA Times	Levator Scapulae Stretch	Grasp seat or leg of chair with right hand to pull shoulder down slightly. Move head forward, rotate and lean to left until stretch from neck to top of shoulder blade is felt. Lean body to left to increase stretch. Hold 15 seconds. Repeat on other side.		Neck side benders, scapular elevators, posterior and lateral ligaments of the upper thoracic and cervical spine and facet joints	fair	chair	somewhat	mini	simple	a b c Avoid rapid stretching. May produce moderate loading on cervical discs if performed in forward, flexed head posture.
21	Pragler	Exercise a-3	Keeping shoulders down, bend the head over towards the shoulder to stretch the muscles of the neck. Hold that position for a count of 3, and then bring head slowly back to the center.		Neck side benders, scapular elevators, lateral ligaments of the upper thoracic and cervical spine and facet joints	poor	chair	no	micro	simple	a b c 4 Avoid rapid stretching. May produce moderate loading on cervical discs if performed in forward, flexed head posture. Enhance safety by tucking chin during side bending.
22	Sauter	Nose Drawing	Close eyes and imagine pen attached to nose. Moving head, draw a large circle. Within circle, draw a plus. Go over it several times. Draw a "X" and go over it several times. Try drawing other objects, or writing name.	Neck sidebenders, rotators, flexors and extensors	Neck sidebenders, rotators, flexors and extensors; posterior and lateral ligaments of the cervical and thoracic spine and facet joints	good	chair	somewhat	mini	simple	a b c 1 3 4
23	Dahl	Unnamed	Lift shoulders towards ears in a shrug, then relax and let them fall back.	Scapular upward rotators and adductors	Scapular downward rotators	*	chair	somewhat	micro	simple	
24	Joyce & Peterson	Shoulder Shrug	Sit straight and bring shoulders up toward ears. Hold for count of 3. Relax. Repeat twice.	Scapular upward rotators and adductors	Scapular downward rotators	good	chair	somewhat	micro	simple	
25	Joyce & Peterson	Shoulder Roll	Sit upright. Lower chin. Slowly make 3 circles with shoulders, then gradually tilt head backward. Make 3 slow circles with shoulders. Stretch upward for count of 3, and relax.	Scapular upward rotators and adductors	Scapular downward rotators cervical flexors and extensors	fair	chair	somewhat	mini	simple	a f 1 3

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Table 1. Panel B. Shoulder Exercises

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
26	Krames Comm.	Shoulders	Roll shoulders forward 5 times using wide circular motions. Then roll shoulders backward 5 times. Repeat cycle 5-10 times.	Scapular upward rotators and adductors, scapular downward rotators and shoulder abductors	Scapular downward rotators and abductors, scapular upward rotators and adductors	good	chair	somewhat	mini	simple	f 1 3
27	Pragiar	Exercise a-6	Circle shoulders backward three times, with arms relaxed by sides.	Scapular upward rotators and adductors, scapular downward rotators and shoulder abductors	Scapular downward rotators and abductors, scapular upward rotators and adductors	good	chair	somewhat	micro	simple	f 1 3
28	Austin	Shoulder Roll	Slowly roll shoulders forward 5 times in circular motion. Then roll back with same circular motion.	Scapular upward rotators and adductors, scapular downward rotators and shoulder abductors	Scapular downward rotators and abductors, scapular upward rotators and adductors	good	chair	somewhat	micro	simple	f 1 3
29	Australian National University	Exercise 3	Circle shoulders backwards and forwards 10-20 times.	Scapular upward rotators and adductors, scapular downward rotators and shoulder abductors	Scapular downward rotators and abductors, scapular upward rotators and adductors	fair	chair	somewhat	mini	simple	f 1 3
30	Sauter	Shoulder Circles	With arms at sides, raise shoulders up, and rotate forward in circular motion several times. Repeat several times in backwards direction.	Scapular upward rotators and adductors, scapular downward rotators and shoulder abductors	Scapular downward rotators and abductors, scapular upward rotators and adductors	good	chair	somewhat	micro	simple	f 1 3
31	Emanuel and Glonek	Shoulder Rotations	Bend elbows and rotate shoulders 4 times forward and 4 times backward.	Scapular upward rotators and adductors, scapular downward rotators and shoulder abductors	Scapular downward rotators and abductors, scapular upward rotators and adductors	fair	chair	somewhat	micro	simple	f 1 3
32	Austin	Arm Circles	Raise arms to side with elbows straight. Slowly rotate arms in small circles, forward and backward.	Scapular upward rotators, shoulder adductors, scapular downward rotators and abductors, shoulder abductors	Scapular downward rotators and abductors, scapular upward rotators and adductors	good	chair	highly	mini	simple	f
33	Krames Comm.	Arm Circles	Raise the arms to the sides, elbows straight. Slowly rotate arms in small circles forwards, then backwards. Lower arms, then repeat 3 times.	Scapular upward rotators, shoulder adductors, scapular downward rotators and abductors, shoulder abductors	Scapular downward rotators and abductors, scapular upward rotators and adductors	good	chair	highly	mini	simple	f
34	Lacey	Upper Arms	Let arms fall to side and rotate hands in circular motion. Put arms up, interlock fingers overhead. Push arms forward, then stretch arms back, pulling ribcage up. Hold arms straight out, rotate them in circular motion. Flex upper arms as in making a muscle.	Wrist flexors, wrist/finger extensors, forearm supinators and pronators, wrist ulnar and radial deviators; shoulder flexors, abductors, external rotators, horizontal abductors and internal rotators	Wrist flexors, wrist/finger extensors, forearm supinators and pronators, wrist ulnar and radial deviators, shoulder extensors, adductors and internal rotators, external rotators and abductors	fair	chair	highly	mini	simple	f j 1 3

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Table 1. Panel B. Shoulder Exercises (cont.)

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
35	Dahl	Unnamed	Sit forward in chair. Slump forward, straighten up and arch back, raise arms as high above head as possible, then slump forward again.	Phase II: Cervical, thoracic and lumbar extensors, scapular adductors, elevators and upward rotators, shoulder flexors and external rotators	Phase I: Shoulder extensors and internal rotators, posterior ligaments of the cervical, thoracic and lumbar spine. Phase II: Cervical, thoracic and lumbar flexors, scalpular adductors, elevators and upward rotators	*	chair	highly	micro	simple	a b c d e 1 3
36	Pragler	Exercise b-7	Push one arm up toward ceiling with hand stretched out. Repeat with other arm.	Scapular adductors and upward rotators; shoulder flexors and abductors, thoracic extensors and external rotators	Shoulder extensors and adductors	good	chair	highly	micro	simple	f
37	Krames Comm.	Reaching High	Raise arms over head, stretching as high as possible. Then bring arms back down. Rest a moment. Repeat 2 times.	Scapular adductors and upward rotators, shoulder flexors and abductors, thoracic extensors	Shoulder extensors, adductors and internal rotators	good	chair	highly	micro	simple	f
38	Gore and Tasker	Reach for the Sky	Standing, stretch arms above head and hold for count of 6. Drop arms. Repeat 5 times.	Scapular adductors and upward rotators, shoulder flexors and abductors, thoracic extensors	Shoulder extensors, adductors and internal rotators	good	work area	highly	mini	simple	f
39	Austin	Reach	Slowly raise arms and draw stomach in. Let arms drop. Repeat twice.	Scapular adductors and upward rotators, shoulder flexors and abductors, thoracic extensors, abdominal flexors	Shoulder extensors, adductors and internal rotators	fair	chair	highly	mini	simple	f
40	Sauter	Arm Stretch	Stretch left arm over head, and right arm towards floor. Hold for several moments. Repeat several times, then reverse arms and repeat.	Scapular adductors and downward and upward rotators, shoulder flexors and abductors, thoracic extensors, neck rotators and flexors	Shoulder extensors and adductors, trunk lateral flexors	good	chair	highly	mini	simple	a b c f 1 3 4
41	LA Times	Windmills	Bring head into Turkey Position (see exercise 5), with arms at sides. Point one thumb forward, one thumb back. With arms straight, move them in direction thumbs are pointing. Repeat, moving arms in opposite direction. Do 3-5 times.	Scapular adductors, downward and upward rotators, shoulder flexors, abductors, external rotators, extensors, adductors and internal rotators, elbow extensors, forearm supinators and pronators, thoracic extensors	Scapular downward and upward rotators, shoulder extensors, adductors, internal rotators, flexors, abductors and external rotators, elbow flexors, forearm pronators and supinators	fair	chair	highly	micro	simple	a f 1 3
42	Australian National University	Exercise 1	With arms bent across chest, push elbows back while stretching head up. Repeat 7-15 times.	Scapular adductors, upward rotators, shoulder vertical and horizontal abductors, external rotators		poor	chair	somewhat	mini	simple	

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Table 1. Panel B. Shoulder Exercises (cont.).

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
43	Austin	Shoulder Stretch	Bring right hand to upper back from above. Bring left hand to upper back from below and hook fingers of two hands. Repeat on other side.	Scapular adductors, downward and upward rotators, shoulder flexors, abductors, external rotators, extensors, adductors and internal rotators, elbow flexors, thoracic extensors	Scapular downward and upward rotators, shoulder extensors, adductors, internal rotators, flexors, abductors and external rotators	fair	chair	highly	micro	difficult	f i j 1 3
44	Joyce & Peterson	Arm Rotation	Extend arms straight ahead at shoulder level. Rotate them so the back of the hands face and touch each other. Hold to count of 3. Then rotate hands so palms face upward with sides of hands touching. Hold to count of 3. Repeat 2 more times.	Shoulder external rotators, flexors, shoulder internal rotators, forearm supinators and pronators	Shoulder internal rotators, external rotators, forearm pronators and supinators	fair	chair	highly	micro	simple	f k 1 3 Arm extension may actually increase neck/shoulder strain.
45	Joyce & Peterson	Give Me Five	Hold arms straight out in front. Make fist. Slowly point knuckles to floor. Hold for count of 3. Slowly straighten out fingers. Then point fingers toward ceiling and hold for count of 3. Repeat 3 times.	Shoulder external rotators, flexors and abductors, scapular adductors and upward rotators, thoracic extensors, finger flexors, wrist and finger extensors	Shoulder internal rotators, extensors and adductors, scapular downward rotators, wrist extensors	good	chair	somewhat	mini	simple	f j 1 3 Arm extension may actually increase neck/shoulder strain
46	Gore and Tasker	Fall Back	Sitting up straight, raise arms above head and clasp hands together. Looking forward, let arms and shoulders fall backwards over back of chair. Hold for slow count of 10. Relax. Repeat 3 times.	Shoulder flexors and abductors, scapular adductors and upward rotators	Shoulder extensors and adductors, anterior ligaments of the thoracic spine and facet joints	good	chair	somewhat	mini	simple	b c d e f 2 Potential for chair tipping backwards.
47	Dahl	Unnamed	Sit forward in chair. Raise arms above head and bend backward over back support.	Shoulder flexors and abductors, scapular adductors and upward rotators	Shoulder extensors and adductors, anterior ligaments of the thoracic spine and facet joints, cervical flexors	*	chair	somewhat	micro	simple	b c d e f 2 Potential for chair tipping backwards.
48	Gore and Tasker	Forwards Lean	Standing, push chair against desk. Stand about 1 meter behind chair, place hands on back of chair while keeping elbows straight, drop head forward between arms while keeping back straight. Hold for count of 10. Relax. Repeat 5 times.		Shoulder extensors and adductors, hip extensors/knee flexors (hamstrings), lumbar extensors, posterior ligaments of the lumbar spine and facet joints, cervical extensors	fair	work area	highly	mini	simple	a b c d e 1 2 3 4 Rolling chair potentially dangerous.
49	Krames Comm.	Upper Back Stretch	Raise hands to shoulders. Using the arms push shoulders back. Keep elbows down. Hold for 15 seconds. Repeat 3 times.	Scapular adductors, upward rotators, shoulder vertical and horizontal abductors, external rotators	Scapular abductors, downward rotators, shoulder internal rotators and horizontal adductors	fair	chair	somewhat	mini	simple	f
50	Austin	For your Arms	Bend elbows, keeping arms parallel to floor, fingers in front of chest. Push arms way out to sides with arms straight. Repeat 5 times.	Scapular adductors, upward rotators, shoulder vertical and horizontal abductors	Scapular abductors, downward rotators, shoulder internal rotators and horizontal adductors	poor	chair	highly	micro	simple	f

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Table 1. Panel B. Shoulder Exercises (cont.)

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
51	Joyce & Peterson	Trapezius Squeeze	Raise arms up and to the sides, with palms facing out. Squeeze shoulder blades together and hold 3 sec. Relax. Repeat 2 more times.	Scapular adductors, upward rotators, shoulder vertical and horizontal abductors, external rotators	Scapular abductors, downward rotators, shoulder internal rotators and horizontal adductors	good	chair	highly	micro	simple	f
52	LA Times	Shoulder Blade	Bring head into Turkey Position (see exercise 5). Hold arms up, elbows bent, with palms facing forward at shoulder height. Pull hands back as if to touch little fingers together. Repeat 3-5 times.	Scapular adductors, upward rotators, shoulder vertical and horizontal abductors, external rotators	Scapular abductors, downward rotators, shoulder internal rotators and horizontal adductors	fair	chair	somewhat	micro	simple	f
53	Joyce & Peterson	Executive Stretch	Lock hands behind head and bring elbows back. Lean back in chair, stretching and arching spine. Hold to count of 3. Relax. Repeat twice.	Scapular adductors, upward rotators, shoulder vertical and horizontal abductors, external rotators, cervical and thoracic extensors	Scapular abductors, downward rotators, shoulder internal rotators and horizontal adductors	good	chair	somewhat	mini	simple	a d f
54	Pragler	Exercise a-2	Hands behind head, tuck chin in and push the back of the head into the hands. Hold that position for a count of 3; relax.	Scapular adductors, upward rotators, shoulder vertical and horizontal abductors, external rotators, cervical and thoracic extensors	Scapular abductors, downward rotators, shoulder internal rotators and horizontal adductors	fair	chair	somewhat	micro	simple	a f
55	Austin	Pectoral Stretch	Grasp hands behind neck and press elbows as far back as possible. Relax. Repeat.	Scapular adductors, upward rotators, shoulder vertical and horizontal abductors, external rotators, cervical and thoracic extensors	Scapular abductors, downward rotators, shoulder internal rotators and horizontal adductors	good	chair	somewhat	micro	simple	a f
56	Dahl	Unnamed	Interlace fingers, turn palms forward, raise arms above head, lower them behind the neck, then down in front of the body again.	Scapular adductors, upward rotators, shoulder flexors and abductors, arm extensors, cervical and thoracic extensors	Scapular abductors, downward rotators, shoulder internal rotators, horizontal and vertical adductors, extensors and internal rotators, scapular adductors, downward rotators	*	chair	somewhat	micro	simple	f i j 1 3
57	Pragler	Exercise b-2	Rotate both shoulders backwards, keeping arms relaxed by sides.	Scapular upward rotators and adductors	Scapular downward rotators	good	chair	somewhat	micro	simple	
58	Pragler	Exercise b-3	Clap hands in front of body, keeping elbows bent and tucked in by sides.	Shoulder external rotators, scapular adductors, downward rotators	Shoulder internal rotators, scapular upward rotators	good	chair	highly	micro	simple	f
59	Gore and Tasker	Triangle	With arms by sides, turn palms outward and move arms backward as far as possible. Hold for count of 10. Relax. Repeat 3 times.	Shoulder external rotators, scapular adductors, downward rotators, horizontal adductor	Shoulder internal rotators, scapular upward rotators, anterior chestwall	good	chair	somewhat	mini	simple	f 3
60	Pragler	Exercise b-1	Pull shoulders back, arms at sides. Hold for count of 3.	Cervical and thoracic extensors, scapular adductors, elevators and upward rotators	Anterior ligaments of the lower thoracic spine, anterior chestwall	good	chair	no	micro	simple	

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Table 1. Panel B. Shoulder Exercises (cont.)

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
61	Sauter	Upper Arm Relaxer	Slowly open and spread arms to sides as when stretching and yawning. Fold arms back toward body tightly. Repeat a few times.	Shoulder external rotators, scapular adductors, downward rotators, shoulder internal rotators, scapular abductors, horizontal abductors and adductors	Shoulder internal and external rotators, scapular upward rotators	fair	chair	somewhat	micro	simple	f 3
62	Pragier	Exercise a-4	Bring arms over the back of the chair with the hands clasped. Stretch arms down towards the floor. Hold for a count of 3 then relax.	Scapular adductors, downward rotators	Scapular upward rotators	fair	chair	somewhat	micro	moderately difficult	d f
63	Sauter	Shoulder Blade Pinch	Move forward slightly in chair. Place hands on edges of chair behind buttocks and try to touch elbows together behind back. Relax and repeat a few times.	Scapular adductors, downward rotators	Scapular upward rotators and abductors	good	chair	somewhat	micro	simple	d f
64	Pragier	Exercise b-8	Push arm forward at shoulder height with the hand stretched out. Repeat with the other arm.	Scapular adductors and downward rotators, shoulder extensors, elbow flexors, wrist extensors, scapular abductors and upward rotators, shoulder flexors, elbow extensors	Scapular abductors and upward rotators, shoulder flexors, elbow extensors, wrist flexors, scapular adductors and downward rotators, elbow flexors	fair	chair	highly	micro	simple	f 1 3
65	Austin	Upper Back Stretch	Sit with hands on shoulders. Try to cross elbows in front. Relax. Repeat.	Scapular abductors, shoulder horizontal adductors, and external rotators	Scapular adductors, shoulder horizontal abductors and internal rotators	good	chair	highly	micro	simple	f 1 3
66	Austin	Middle-Upper Back Stretch	Hold right arm just above elbow with left hand. Gently pull elbow toward left shoulder. Hold 5 seconds. Repeat other side.	Scapular abductors, shoulder horizontal adductors	Scapular adductors, shoulder horizontal abductors	good	chair	somewhat	micro	simple	f 1 3
67	Austin	Hug Yourself	Cross arms in front of chest and reach fingertips towards shoulder blades.	Scapular abductors, shoulder horizontal adductors	Scapular adductors, shoulder horizontal abductors	fair	chair	highly	micro	simple	f 1 3

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Table 1. Panel C. Elbow/Lower Arm Exercises.

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
68	Gore and Tasker	Eiffel Tower	Straighten fingers and spread apart as far as possible. Bring whole length of fingers together, but keep palms as far apart as possible. Hold for count of 10. Relax. Repeat 3 times.		Finger flexors, anterior ligaments of the MP joints, finger adductors	poor	chair	somewhat	mini	simple	i j
69	Australian National University	Exercise 12	Raise arms above head with palms and heel of hands together. Slowly pull hands down in front of chest with hands together. Repeat 5-10 times.	Shoulder flexors, abductors and external rotators	Finger flexors, anterior ligaments of the finger joints, shoulder extensors, adductors and internal rotators	good	chair	highly	mini	simple	i j
70	Gore and Tasker	Palm Press	Place palms together, point fingers to ceiling. Keeping palms together, try to push heels of hands towards floor and hold for count of 10.		Finger flexors, anterior ligaments of the finger joints	fair	chair	somewhat	micro	simple	i j
71	Dahl	Unnamed	Place palms together and press one hand backwards with the other. Change hands.		Finger flexors, anterior ligaments of the finger joints	*	chair	somewhat	micro	simple	i j
72	Austin	Wrist Flex	Put elbow on table with hand raised. With other hand, hyperextend wrist so that the back of the first hand is aiming to the top of the forearm. Repeat with opposite hand.		Finger flexors, anterior ligaments of the finger joints	fair	chair	somewhat	micro	simple	j
73	Krames Comm.	Wrist Flex	Put your right elbow on a table, hand raised. With your left hand, gently band your right hand back toward the forearm. Hold 5 seconds. Repeat on the other side.		Finger flexors, anterior ligaments of the finger joints	good	chair	somewhat	micro	simple	i j
74	Dahl	Unnamed	Bend wrist backward. With other hand, grasp tips of fingers and pull hand backward. Repeat with other hand.		Finger flexors, anterior ligamente of the finger joints	*	chair	no	micro	simple	i j
75	Joyce & Peterson	Thumb Stretch	Stretch right hand out. Gently pull the thumb down and back. Hold 5 sec. Relax and repeat 2 times. Repeat with left hand.		Thumb flexors and adductors	fair	chair	somewhat	mini	simple	i j
76	Krames Comm.	Wrist	Hold hands in front of body. Raise and lower hands to stretch muscles in forearm. Repeat several times	Wrist/finger extensors, shoulder flexors	Wrist extensors and flexors	poor	chair	somewhat	micro	simple	f i 1 3 Arm extension may actually increase neck/shoulder strain.
77	Australian National University	Exercise 9	Lift arms forward, slowly clench fists, open and spread fingers. Repeat 10-20 times.	Finger flexors and extensors, shoulder flexors	Finger flexors and extensors	good	chair	somewhat	mini	simple	f i 1 Arm extension may actually increase neck/shoulder strain.
78	Krames Comm.	Finger Fan	Hold hands out in front of body, palms down. Spread fingers apart as far as possible. Hold for 5 seconds, then make a tight fist. Repeat 3 times.	Finger flexors and extensors, finger abductors	Finger flexors and extensors, finger adductors	good	chair	somewhat	micro	simple	i j 1 3

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Table 1. Panel C. Elbow/Lower Arm Exercises (cont.)

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
79	Dahl	Unnamed	Spread and stretch fingers as much as possible, then make a fist.	Finger flexors and extensors, finger abductors	Finger flexors and extensors, finger adductors	*	chair	no	micro	simple	i j 1 3
80	Austin	Fingers	With palms down, spread thumb and fingers as far apart as possible. Hold for count of 5. Relax. Repeat.	Wrist/finger extensors, finger abductors	Finger flexors, finger adductors	good	chair	no	micro	simple	i j
81	Sauter	Palm Push-Ups	Place tops of hands under front edge of worktable. Push up with hands (not arms) for a moment. Then place palms in similar position on top of desk and push down. Drop hands to sides and wiggle hands a bit. Rest in lap for a few seconds.	Finger extensors, wrist extensors		good	chair	no	micro	simple	k
82	Australian National University	Exercise 10	Lift arms forward, circle hands at wrist, then reverse. Drop hands to sides, repeat circling. Raise arms above head, repeat circling. Do 5 times each direction, each position.	Wrist flexors, wrist/finger extensors, forearm supinators/pronators, wrist ulnar and radial deviators, shoulder flexors, abductors and external rotators	Wrist flexors, wrist/finger extensors, forearm supinators/pronators, wrist ulnar and radial deviators, shoulder extensors, adductors and internal rotators	good	chair	highly	mini	simple	f i j k 1 3 May increase joint stress in the wrist. Arm extension may actually increase neck/shoulder strain.
83	LA Times	Forearm Stretch	Bend elbow so palm is facing forward. Make fist. Bend wrist so palm surface points to floor. Turn hand so it points away from body, then straighten forearm and turn arm inward. Hold 15 seconds. Repeat 3-5 times.	Wrist/finger flexors, forearm pronators	Wrist/finger extensors, forearm supinators	fair	chair	somewhat	mini	simple	i j k 1 3
84	Australian National University	Exercise 11	Bend wrist and fingers of one hand towards palm, applying pressure with other hand. Repeat with other hand. Do 5-10 times.		Wrist extensors	fair	chair	no	mini	simple	i j
85	Sauter	Finger Curls	Holding forearms outstretched in front, bend fingers (not hands) downward and curl them into a fist. Open fist and bend fingers up slightly. Repeat once or twice. Return fingers to neutral position and stretch them apart. Drop arms and hands to sides and gently wiggle them about for a moment. Return hands to lap and rest them for a few seconds.	Finger flexors and extensors	Finger flexors and extensors	good	chair	somewhat	micro	simple	i j 1 3

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Table 1. Panel D. Lower Back/Hip Exercises.

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
86	Sauter	Sack Arch	Move forward slightly in chair and place hands on edges of chair. Straighten up slowly, raising chest up and out. Hold momentarily. Relax. Repeat a few times.	Upper cervical, thoracic and lumbar extensors, scapular adductors, elevators and upward rotators, neck flexors	Upper cervical extensors Phase II: anterior ligaments of the upper cervical, thoracic and lumbar spine	good	chair	somewhat	micro	simple	a b d f l
87	Austin	Knee Kiss	Sit in chair. Pull one leg to chest, grasp with both hands and hold for count of five. Repeat with opposite leg.	Arm flexors, shoulder extensors	Hip extensors, lower cervical and thoracic extensors and posterior ligaments of the cervical, thoracic and lumbar spine	good	chair	highly	mini	difficult	b c d e f i l m 2 4 Rolling chair potentially hazardous. Difficult to perform in most office attire, or for obese individuals.
88	Krames Comm.	Legs	Grasp shin of one leg and pull slowly toward chest. Hold 5 sec. Repeat several times with both legs.	Arm flexors, shoulder extensors	Hip extensors, lower cervical and thoracic extensors and posterior ligaments of the cervical, thoracic and lumbar spine	good	chair	highly	mini	difficult	b c d e f i l m 2 4 Rolling chair potentially hazardous. Difficult to perform in most office attire, or for obese individuals.
89	Austin	Back Relaxer	Sit on chair. Drop neck, shoulders and arms, then bend down between knees, as far as possible. Return to upright position. Straighten out and relax.		Thoracic and lumbar extensors, posterior ligaments of the thoracic and lumbar spine	good	chair	highly	mini	simple	b c d e 1 2 3 Awkward to perform. Rolling chair potentially hazardous. Difficult to perform in most office attire. Difficult to perform for obese or pregnant individuals.
90	Krames Comm.	Lower Back Stretch	Lower head and slowly roll body as far as possible toward knees. Hold for 10 seconds. Push self up with leg muscles. Repeat 3 times.		Thoracic and lumbar extensors, posterior ligaments of the thoracic and lumbar spine	fair	chair	highly	mini	moderately difficult	b c d e 1 2 3 Awkward to perform. Rolling chair potentially dangerous (as noted in brochure). Difficult to perform for obese or pregnant individuals.
91	Lee and Walker	Bending	Bend trunk forward as far as possible, letting arms hang loose. Stretch trunk back, placing hands on small of back.		Phase I: Thoracic and lumbar extensors, posterior ligaments of the thoracic and lumbar spine, hip extensors and knee flexors (hamstrings) Phase II: Anterior ligaments of the lumbar spine and hip joints, trunk and hip flexors	good	work area	highly	mini	moderately difficult	b c d e 1 2 3 Awkward and difficult to perform for obese or pregnant individuals.
92	Dahl	Unnamed	Sit forward in chair. 1) Slump forward, 2) straighten up and arch back, then slump forward again.	Neck flexors Phase II: Lower cervical, thoracic and lumbar extensors	Phase I: Lower cervical, thoracic and lumbar extensors, scapular adductors, elevators and upward rotators, posterior ligaments of the cervical, thoracic and lumbar spine Phase II: Upper cervical flexors, anterior ligaments of the lower cervical and thoracic spine	*	chair	no	micro	simple	a b c d e 1 3
93	Joyce & Peterson	Pelvic Tilt	Sit straight in chair. Tighten abdominal muscle. Slowly tilt pelvis by pressing waist into back of chair. Hold 3 sec. Relax. Tilt pelvis in other direction by arching back. Repeat 2 more times.	Phase I: Trunk flexors, hip extensors. Phase II: Trunk extensors and hip flexors	Phase I: Thoracic and lumbar extensors, and posterior ligaments of the lumbar and thoracic spine. Phase II: Hip extensors	good	chair	no	micro	simple	b c d e 4 Avoid strong pelvic tilt contractions as they may increase stress to the lumbar discs.

*As the Dahl exercises were translated from Danish to English for the authors, the specificity of the instructions was not evaluated

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k Acute lateral epicondylitis
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Table 1. Panel D. Lower Back/Hip Exercises (cont.)

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
94	Sauter	Pelvic Tilt	Imagine you have a tail and are trying to tuck it between your legs by tilting the pelvis up. Hold 1-2 sec. Repeat a few times.	Trunk flexors and hip extensors	Posterior ligaments and extensors of the lumbar spine	good	chair	no	micro	simple	b c d e 4 Avoid strong pelvic tilt contractions as they may increase stress to the lumbar discs.
95	Joyce & Peterson	Glute Clench	Sit straight, tighten both buttock and abdominal muscles, hold for 5 seconds. Relax, then repeat 2 more times.	Trunk flexors and hip extensors		fair	chair	no	micro	simple	b c d e 4 Avoid strong pelvic tilt contractions as they may increase stress to the lumbar discs.
96	Austin	Windmill	Sit in chair. Place feet apart on the floor. Bend over and touch right hand to left foot with left arm extended up. Alternate sides repeatedly.	Anterior and posterior trunk rotators, thoracic, lumbar and hip extensors, trunk side benders	Anterior and posterior trunk rotators, thoracic, lumbar and hip extensors, trunk side benders, posterior and lateral ligaments of the thoracic and lumbar spine	good	chair	highly	mini	difficult	a b c d e f l 1 2 3 4 Avoid rapid stretching. Difficult to perform for obese or pregnant individuals. Rolling chair potentially hazardous. Difficult to perform in most office attire.
97	Austin	Trimming the Waist'	Interlace fingers behind neck. Lift right knee and touch left elbow to right knee. Alternate sides 5 times.	Hip flexors, anterior and posterior trunk extensors and rotators	Anterior and posterior trunk rotators, thoracic, lumbar and hip extensors, trunk side benders, posterior and lateral ligaments of the cervical, thoracic and lumbar spine	good	chair	highly	mini	moderately difficult	a b c d e f 1 2 3 4 Rapid stretching not recommended. Rolling chair potentially hazardous.
98	Dahl	Unnamed	Sit forward in chair. Put hands on seat behind body, extend and raise both legs. Relax.	Hip and trunk flexors, knee extensors	Hip extensors and knee flexors (hamstrings)	*	chair	somewhat	micro	moderately difficult	b c d e f l 1 2 3 4 Hip flexors are often already tight as a result of the sedentary nature of VDT work. Rolling chair potentially hazardous.
99	Joyce & Peterson	Knee Raises	Sit upright in chair. Tighten abdominal muscles and raise knees 2 inches. Hold 3 sec. Relax. Repeat 2 times.	Hip and trunk flexors, trunk anterior and posterior rotators		good	chair	somewhat	mini	moderately difficult	b c d e 1 3 4 Hip flexors are often already tight as a result of the sedentary nature of VDT work. Rolling chair potentially hazardous.
100	Austin	Side Stretch	Interlace fingers. Lift arms over head and press backwards as far as possible. Lean to the left, then to the right.	Trunk side benders, shoulder flexors, abductors and internal rotators, scapular adductors, elevators and upward rotators	Trunk side benders, shoulder extensors, adductors and internal rotators, posterior and lateral ligaments of the thoracic and lumbar spine	good	chair	highly	micro	simple	b c d e f l j 1 3 4
101	Australian National University	Exercise 7	Arms by side, creep hand down thigh toward knees. Repeat on other side. Do 5-10 times.	Trunk side benders	Trunk side benders, lateral ligaments of the thoracic and lumbar spine	fair	work area	highly	mini	simple	b c d e l 1 4 Rapid stretching not recommended.
102	Gore and Tasker	Sideways Bend	Standing with arms at sides, bend sideways so right arm goes down right leg. Return to upright and repeat on left side. Repeat 5 times each side.	Trunk side benders	Trunk side benders, lateral ligaments of the thoracic and lumbar spine	good	work area	highly	mini	simple	b c d e l 1 4 Rapid stretching not recommended.
103	Lee and Walker	Side Bending	Bend to left as far as possible, letting left arm hang loose. Repeat on right side.	Trunk side benders	Trunk side benders, lateral ligaments of the thoracic and lumbar spine	good	work area	highly	mini	simple	b c d e l 1 4 Rapid stretching not recommended.

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Table 1. Panel D. Lower Back/Hip Exercises (cont.).

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
104	Pragler	Exercise b-4	Bend to left and stretch left arm down side. Repeat to right.	Trunk side benders	Trunk side benders, lateral ligaments of the thoracic and lumbar spine	good	work area	highly	mini	simple	b c d e l 1 4 Rapid stretching not recommended.
105	Sauter	Chair Rock	Place feet squarely on floor with hands at side of chair. Rock slowly to left, looking over right shoulder, then to the right, looking over left shoulder. Do several times.	Anterior and posterior cervical, thoracic, and lumbar rotators	Anterior and posterior cervical and thoracic and lumbar rotators, posterior and lateral ligaments of the cervical, thoracic and lumbar spine	good	chair	highly	micro	simple	a b c d 4 May produce moderate loading on cervical discs if performed with forward head posture.
106	Austin	Trunk Twists	Turn at trunk. Turn head in direction of trunk. Twist 3 times in each direction.	Anterior and posterior trunk rotators, shoulder abductors and external rotators, scapular adductors, elevators and upward rotators, neck rotators	Anterior and posterior trunk rotators, posterior and lateral ligaments of the thoracic and lumbar spine, shoulder internal rotators	good	chair	highly	micro	simple	a b c d e f l 1 3 4 Raised arms (as shown in the brochure) produce additional loading on lumbar and thoracic discs.
107	Emanuel and Glonek	Trunk Rotations	Rotate entire upper body in a clockwise direction 3 times. Repeat counter-clockwise 3 times.	Anterior and posterior trunk rotators, trunk side benders, trunk/hip flexors and extensors	Anterior and posterior trunk rotators, trunk side benders, trunk/hip flexors, anterior and lateral ligaments of the lumbar and thoracic spine and hip joints	fair	work area	highly	micro	simple	b c d e l 1 4
108	Australian National University	Exercise 6	Place palms across the small of back, bend and arch spine. (5-10 times)	Abdominals (eccentric)	Anterior ligaments of the lumbar spine and hips, trunk and hip flexors	poor	work area	somewhat	mini	simple	b d e l
109	Gore and Tasker	Disc Reliever	Standing up straight with feet slightly apart, place hands in hollow of back. Focus eyes on a point straight ahead. Bend backwards over hands without bending knees, then straighten up. Repeat 10 times.	Abdominals (eccentric)	Anterior ligaments of the lumbar spine and hips, trunk and hip flexors	good	work area	somewhat	mini	moderately difficult	b d e l
110	Austin	Derriere Firmer	Place hands on chair, feet flat on floor, lift hips and buttocks up. Tighten buttocks and hold for 5 sec. Sit back and relax. Repeat twice.	Hip adductors/extensors, back extensors, scapular adductors, arm and shoulder extensors	Hip/trunk flexors, shoulder flexors	good	chair	highly	mini	difficult	b c d e f l 2 Arm strength limits ability to perform. Rolling chair potentially hazardous. May be difficult for obese or pregnant individuals to perform.

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Table 1 Panel E. Knee/Lower Leg Exercises.

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
111	Dahl	Unnamed	Standing, extend one leg backwards and upwards. Grab foot and pull upwards. Repeat with other leg.		Knee extensors, anterior ligaments of the hip, hip flexors	*	work area	highly	mini	difficult	b c d e m 2 Support should be provided when performing standing portion of the exercise. Difficult to perform in most office attire, or in high-heeled shoes.
112	Australian National University	Exercise 14	Hands on hips, one foot in front of other, rock forward and backward slowly 10-20 times. Repeat with other leg.	Hip abductors and extensors, knee extensors	Plantar flexors, hip flexors and external rotators, anterior ligaments of the hips	fair	work area	highly	mini	moderately difficult	m
113	Dahl	Unnamed	Standing, take long step forward and bend knee. Keep heel of rear foot on floor. Bend front knee joint further to lower body downward. Repeat with other leg.	Hip abductors and extensors, knee extensors	Plantar flexors, hip flexors and external rotators, anterior ligaments of the hip	*	work area	highly	mini	moderately difficult	m 2 Support should be provided. Difficult to perform in most office attire, or in high-heeled shoes.
114	Gore and Tasker	Calf Lengthener	Stand with one leg behind the other in lunge position, keeping heel of back foot on floor, lean forward onto front leg. Hold for count of 10. Repeat 3 times per leg.	Hip abductors and extensors, knee extensors	Plantar flexors, hip flexors and external rotators, anterior ligaments of the hip	good	work area	highly	mini	moderately difficult	m 2 Support should be provided. May be hazardous for individuals with ankle problems. Difficult to perform in most office attire, or in high-heeled shoes.
115	Australian National University	Exercise 8	With one foot in front of other, lean forward from hip, supporting arm on forward thigh. Circle free arm. Repeat other side. Do 5-10 times.	Hip abductors and extensors, knee extensors	Plantar flexors, hip flexors and external rotators, anterior ligaments of the hip	poor	work area	highly	mini	moderately difficult	m 2 Support should be provided. Difficult to perform in most office attire, and in high-heeled shoes.
116	Australian National University	Exercise 13	Standing with hands on hips, place feet apart and rock from side to side, bending alternate knees 10-20 times.	Hip abductors and extensors, knee extensors		fair	work area	highly	mini	simple	m
117	Pragler	Exercise b-5	Walk on the spot, letting shoulders and arms hang loose.	Hip abductors and extensors, knee extensors		good	work area	somewhat	mini	simple	m
118	Dahl	Unnamed	Walk up stairs rather than using the elevator.	Hip abductors and extensors, knee extensors, hip flexors, hamstrings		*	extra-work area	no	major	simple	c d m 4
119	Pragler	Exercise b-6	Hop on left foot, then on right foot.	Plantar flexors, knee extensors, hip extensors/abductors		good	work area	highly	micro	moderately difficult	c d e m 4 Exercise creates too much impact through knees, hips and back. Difficult to perform in high-heeled shoes.
120	Emanuel and Glonek	Stretching	Stand on tip toes, extend hands as far as possible overhead. Lower arms slowly to side of body, continuing to extend arms as far as possible.	Plantar flexors, knee extensors, scapular adductors and upward rotators, shoulder flexors, abductors, and external rotators, thoracic extensors	Shoulder extensors, adductors and internal rotators, abdominals	fair	work area	highly	mini	simple	f 2 Difficult to perform in high-heeled shoes.

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Table 1. Panel E. Knee/Lower Leg Exercises (cont.)

	Author	Name of Exercise	Exercise Instructions	Muscle Groups Recruited	Anatomical Structures Stretched	Specif. of Instr.	Space or Location	Conspicuous?	Time Reqmt.	Ease of Perform.	Comments
121	Emanuel and Glonek	Relaxing	Let arms hang loose, try to relax arms, shoulders and knees. Bounce up and down on toes for a few seconds.	Plantar flexors		good	work area	somewhat	mini	simple	2 Difficult to perform in high-heeled shoes.
122	Austin	Strengthen the Quadriceps	Bring legs straight out in front of body in L-shaped position. Hold 5 sec. Relax. Repeat.	Knee extensors, hip flexors, back flexors	Hip extensors and knee flexors (hamstrings)	good	chair	somewhat	micro	difficult	b c d a 1 2 4 Hip flexors already tight as a result of sitting for long periods. Rolling chair potentially hazardous.
123	Dahl	Unnamed	Sitting, extend one leg and flex the foot up and down. Repeat with other leg.	Ankle dorsiflexors, invertors and evertors, knee extensors	Hamstrings	*	work area	somewhat	micro	simple	m
124	Sauter	Leg Reach and Toe Circles	While seated, hold onto chair and raise and extend one leg out in front. Draw a couple of circles in the air with foot, using toe as pointer. Slowly bend knee and bring it about one third of way toward chest. Extend leg again and relax. Repeat exercise with each leg several times.	Ankle dorsiflexors, invertors and evertors, knee extensors	Hamstrings, hip extensors	good	chair	highly	mini	simple	b c d a m 4 May be difficult to perform by obese or pregnant individuals. Difficult to perform in most office attire.
125	Joyce & Peterson	Legs/Ankles/Feet	While sitting, slowly rotate each foot from ankle three times in one direction, then three times in the other. Point toes downward as far as possible. Hold three seconds. Then point toes straight up and hold three seconds. Repeat three times.	Ankle dorsiflexors, invertors and evertors		good	work area	no	mini	simple	
126	Pragler	Exercise a-5	Sitting in chair, lift right leg, hold out straight, then move foot up and down from ankle 10 times. Circle foot to right 10 times, then to left 10 times. Repeat with left leg.	Ankle dorsiflexors, invertors and evertors, knee extensors	Hamstrings	good	chair	no	mini	simple	
127	Sauter	Foot Presses	Sitting erect in chair, press down alternately with ball and heel of right foot several times. Repeat with other foot.	Ankle dorsiflexors, plantar flexors		good	chair	no	micro	simple	

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Table 2. Proportion of exercises, by body part, falling within each of the useability assessment categories.

	Specificity of Instructions			Location			Conspicuousness			Time Requirement			Ease of Performance		
	Good	Fair	Poor	Chair	Work Area	Extra Work Area	No	Somewhat	Highly	Micro	Mini	Major	Simple	Mod. Difficult	Difficult
Neck	0.61	0.35	0.04	0.92	0.08	0.00	0.24	0.68	0.08	0.52	0.48	0.00	1.00	0.00	0.00
Shoulder	0.56	0.38	0.05	0.95	0.05	0.00	0.02	0.52	0.45	0.64	0.36	0.00	0.95	0.02	0.02
Elbow/Lower Arm	0.53	0.33	0.13	1.00	0.00	0.00	0.28	0.61	0.11	0.61	0.39	0.00	1.00	0.00	0.00
Lower Back/Hip	0.78	0.17	0.04	0.68	0.32	0.00	0.16	0.20	0.64	0.40	0.60	0.00	0.60	0.24	0.16
Knee/Lower Leg	0.69	0.23	0.08	0.24	0.71	0.06	0.24	0.24	0.53	0.24	0.71	0.06	0.59	0.29	0.12
All Exercises	0.63	0.31	0.06	0.80	0.19	0.01	0.16	0.46	0.38	0.51	0.48	0.01	0.85	0.09	0.06

all are suitable for performance at the workstation, or even in the workplace. Each exercise was categorized according to the location most suitable for performance. Three categories were utilized: chair, work area and extra-work area.

- *Chair* The exercise can be performed while seated at the workstation.
- *Work area* The exercise can be performed in close proximity to the workstation.
- *Extra-work area* The exercise does not lend itself to performance at the work area due to the required postures, or the inappropriateness of work attire for such an activity.

Conspicuousness This dimension is important because it addresses the issues of modesty and fear of embarrassment. Highly conspicuous exercises may be less likely to be accepted by VDT users, or may not be performed as instructed. Three categories were defined: highly conspicuous, somewhat conspicuous, or not conspicuous.

- *Highly conspicuous* Potentially embarrassing to the user or dramatically different from routine movements.
- *Somewhat conspicuous* Somewhat obvious to others, but socially acceptable and not embarrassing because of the similarity to common movements (eg, spontaneous stretch associated with fatigue).
- *Not conspicuous* Neither obvious nor embarrassing.

Time requirement/disruption of the work process The exercises varied in the amount of time required to perform them, or in the degree to which they could interrupt work. Excessive or repeated disruption of work may interfere with the work rhythm and impair performance, leading to lack of acceptance by employers or individual VDT users. Three categories were defined: microbreaks, minibreaks and major breaks.

- *Microbreak* Very short break required (ie, less than 10–15 s), entailing no significant interruption of work.
- *Minibreak* A break of less than 1–2 min in duration is required; interruption of the work task is usually necessary.
- *Major break* The exercises can be performed only during a formal break from the task/work area lasting several minutes or more.

Ease of learning and performance This dimension refers to the complexity of the exercises, a factor also potentially affecting acceptance and performance of the exercise routine by VDT users. Three rating categories were defined: simple, moderately difficult, or difficult.

Physiotherapeutic assessment

The potential for three types of problems was considered in the analysis of each exercise. The 'Comments' column in Table 1 notes limitations pertinent to these issues (see also Table 3)

Aggravation of pre-existing health conditions Some medical conditions (eg, acute low back pain) may be aggravated by exercise or may limit performance of an

Table 3. Proportion of exercises, by body part, falling within each of the physiotherapeutic assessment categories.

	Reprods physical stresses of VDT work	Stretches over-stretched structures	Places additional loads on discs	Poses one or more safety hazards	Health contra-indications
Neck	0.36	0.44	0.40	0.00	0.72
Shoulder	0.45	0.50	0.05	0.07	0.93
Elbow/Lower Arm	0.39	0.33	0.00	0.00	1.00
Lower Back/Hip	0.60	0.40	0.68	0.36	1.00
Knee/Lower Leg	0.06	0.00	0.23	0.41	0.82
All Exercises	0.40	0.38	0.26	0.15	0.90

exercise. These conditions are noted in the 'Comments' column of Table 1.

Replication/exacerbation of physical stresses associated with the task Some exercises reproduce or exacerbate postural or biomechanical demands of the job. Examples are exercises which stretch spinal muscles and ligaments already overstretched as a result of sitting for long periods in a fixed spinal posture, or wrist hyperextension-flexion exercises which may exacerbate the physical demands of keyboard work.

Safety/therapeutic/performance issues Exercises were also analysed for their potential to create a safety hazard when performed in an office setting (eg, use of mobile office furniture as props), or by certain populations of users (eg, obese or pregnant individuals). Additionally, it was noted when an exercise would be awkward or impossible to perform in typical women's office attire (eg, dress or skirt; high heels).

The usability of physiotherapeutic-safety judgements were arrived at by consensus among the authors. The authors first performed the evaluations individually, then met as a group to resolve any differences. (Each author's area of expertise is as follows: K Lee, biomechanics; N Swanson and S Sauter, office ergonomics; R Wickstrom, biomechanics and physical therapy (RPT); A Waikar, biomechanics; M. Mangum, exercise physiology.)

Results

Nature of the exercises

The exercises were rather unevenly distributed among the classified body parts: neck (n = 25), shoulder (n = 42), elbow/lower arm (n = 18), lower back/hip (n = 25) and knee/lower leg (n = 17). For the most part, the underlying objectives of the evaluated exercises were to relax or stretch chronically tense muscles, to increase flexibility or mobility, and to improve circulation.

Usability and physiotherapeutic assessments

Below is a summary of the usability and physiotherapeutic ratings for the exercises, organized according to targeted body part. The specific rating of each of the 127 exercises on all usability and physiotherapeutic dimensions is presented in Table 1. Tables 2 and 3 give the proportion of exercises receiving each rating within each usability/physiotherapeutic dimension (also organized according to targeted body part).

Implicit in our evaluation is the assumption that those exercises that are least conspicuous, disruptive and most easily performed (preferably at the work station) are most likely to be adopted in a typical office workplace. Our assessment of the utility of these exercises may vary somewhat depending upon employers' willingness to set aside special breaks and places for individual or group exercises by workers. However, even then, some workers may not perform the exercises because of embarrassment or difficulty in performance.

Neck exercises (Table 1, panel A)
Usability assessment There are 25 neck and upper-back exercises designed to offset problems that are very common to VDT operation such as stiffness or soreness associated with long-term shoulder retraction during data entry tasks. All exercises can be performed easily, 61% had good instructions, and all but two (1, 18) can be performed while seated. Approximately half (52%) of the exercises can be performed without significant disruption of the work routine, and most (92%) were judged to be fairly inconspicuous (ie, mimicked natural movements).

Physiotherapeutic assessment Some of the exercises may be somewhat uncomfortable or difficult to perform by individuals with acute neck pain, degenerative disc disease, osteoporosis, etc. Over one third (36%) of the exercises reproduced the physical stresses of VDT work, most further stretching muscles and ligaments which were already overstretched owing to sitting in a flexed spinal posture for long periods of time. Additionally, over one third (40%) of the exercises may place additional loads on already loaded cervical and thoracic discs.

Shoulder exercises (Table 1, panel B)
Usability assessment There are 42 shoulder exercises designed to stretch and relieve tension in the upper back and to enhance the range of motion of the shoulders. Over half (56%) of the exercises have good instructions and all but two exercises (38, 48) can be performed while seated. However, one third (36%) of the exercises are somewhat disruptive of work since they require several minutes to perform, and nearly half (45%) of the exercises were judged to be highly conspicuous. All but two exercises (43, 62) are simple to perform.

Physiotherapeutic assessment Most (88%) of the shoulder exercises may be contraindicated for individuals with acute inflammatory or arthritic conditions of the shoulder (see, for example, Figure 1 (a)). Nearly half (45%) of the exercises reproduce some of the physical stresses of VDT work, primarily in further stretching chronically stretched structures. Three exercises (46–48), all of which require the use of a chair as a prop, pose potential safety hazards because the required exercise movements may cause the chair to roll, or to tip backwards.

Elbow/lower arm exercises (Table 1, panel C)
Usability assessment There are 18 elbow/lower arm exercises, many designed to enhance the flexibility of the fingers and wrists. About half (53%) have good instructions, all can be performed while seated, and many (61%) can be performed without significant disruption of the work routine since they require only a few seconds to perform. Most (89%) of the exercises are inconspicuous or only moderately conspicuous. None are difficult to perform.

Physiotherapeutic assessment Most (83%) of the exercises may be problematic for individuals with hand/wrist disorders owing to the extreme postural angles

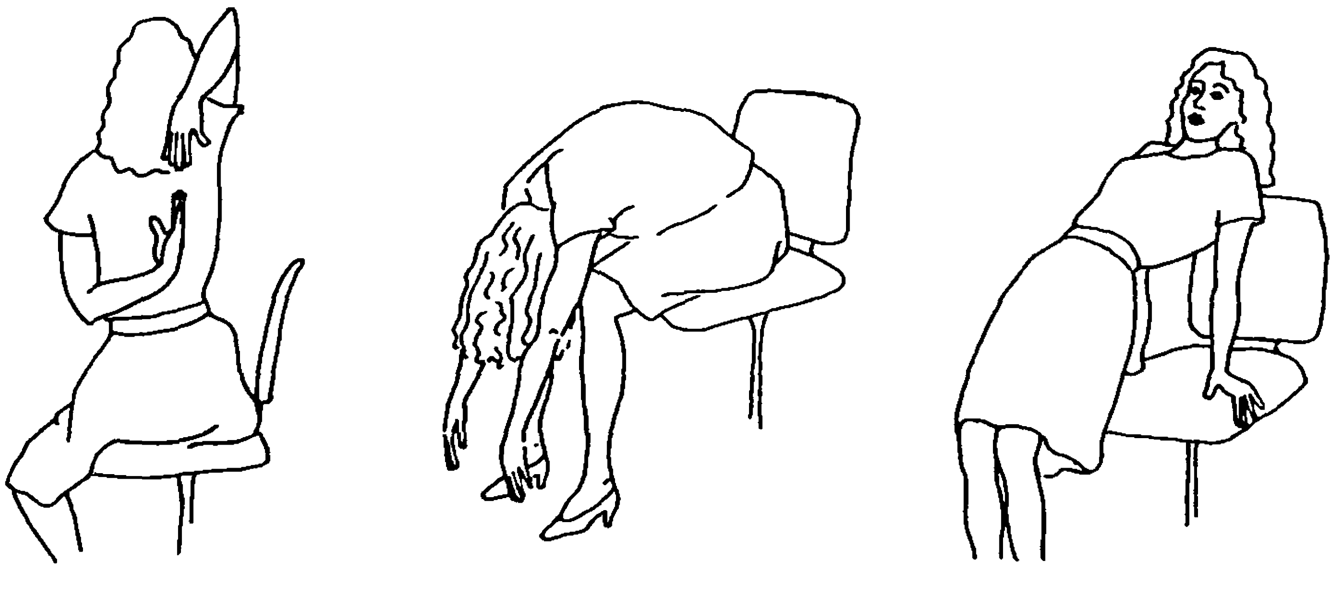

Figure 1 Examples of exercises which (a) had the potential to exacerbate existing health conditions, (b) replicated the stresses of VDT work, or (c) posed potential safety hazards

created in the performance of the exercises. For example, exercises 72–74 require that the wrist of one arm be manually hyperextended with the other hand. Additionally, most of the exercises may be contra-indicated for individuals with arthritic conditions of the hands and wrist, and several others (76, 77, 81–83) may be contraindicated for those with lateral epicondylitis or inflammatory conditions of the shoulder. Additionally, three exercises (76, 77, 82) involve static arm extensions of some duration which may actually exacerbate the neck/shoulder strain arising from VDT work.

Lower back/hip exercises (Table 1, panel D)
Usability assessment There are 25 lower back/hip exercises designed mainly to stretch the muscles that act directly on the vertebral column (eg, the erector spinae), and also muscles that act as prime movers elsewhere, but impact on the vertebral column and lower back (eg, the hamstrings). The majority (78%) of the exercises had good instructions. However, many are potentially disruptive owing to time and posture requirements (standing, upper body movement). Nearly two thirds (60%) required a break of several minutes to perform, and 64% were judged to be highly conspicuous. Only four (92–95) were inconspicuous. Over one third (40%) of the exercises are moderately difficult or difficult to perform, especially for obese people, as these exercises involve touching the toes, or lifting the legs to the chest, from a seated position.

Physiotherapeutic assessment All of the exercises may be contraindicated for individuals with low back pain, degenerative disc disease or osteoporosis, or for women in the second or third trimesters of pregnancy, as extreme flexion or extension of the lumbar region is often required. A number of the exercises (60%) reproduce the physical stresses of VDT work, primarily in producing additional loads to the lumbar region (see Figure 1 (b)). Over one third (36%) of the exercises posed safety hazards owing to the potential for an office chair, which is used as a support, to roll while the exercise is being performed (see Figure 1 (c)). Additionally, four exercises (87–89, 96) would be difficult to perform in most women's semi-formal office attire.

Knee/lower leg exercises (Table 1, panel E)
Usability assessment There are 17 knee/lower leg exercises. The primary intent of these exercises is to stretch muscles and to offset poor circulation associated with prolonged sitting and constrained postures. Nearly three quarters (69%) of the exercises had good instructions. However, all would disrupt work to some extent since either minibreaks, a standing posture, or use of both hands is required. Over half of the exercises (53%) are highly conspicuous and 41% are moderately difficult or difficult to perform.

Physiotherapeutic assessment Over half of the exercises (64%) are contraindicated for individuals with arthritic conditions of the hips and/or knees. Additionally, exercises 111 and 113–15 create the potential for a fall if adequate support is not provided during performance, and eight exercises (111, 113–15, 119–121, 124) would be difficult or impossible to perform for individuals wearing high heels or typical women's office attire.

Discussion

In general, the results of this evaluation showed that a considerable number of exercises recommended for VDT users have some features which would facilitate their acceptance and performance in a typical office workplace. For example, the instructions for the majority of the exercises were clear, and most of the exercises were simple to perform.

The neck and elbow/lower arm exercises had the best overall evaluations on the five usability criteria. Most had clear instructions (58%), could be performed without leaving the chair (95%), were inconspicuous, or mimicked natural body movements (91%), could be performed in a brief period of time (56%), and were simple to perform (100%). On the other hand, the majority of the lower back/hip and knee/lower leg exercises were disruptive because they were highly conspicuous (58%) and/or required interruption of the work task to perform (ie, required standing posture or several minutes to perform). The shoulder exercises were intermediate in that they were judged positively on all the usability criteria except conspicuousness. A large number of the shoulder exercises (45%) were highly conspicuous, primarily because of the arm movements required.

Surprisingly, quite a high proportion (90%) of the exercises may be contraindicated for individuals with one or more acute or chronic musculoskeletal disorders, such as osteoporosis or lower back pain. Individuals with such conditions are advised to seek medical approval before performing these exercises. Of especial concern, however, was the finding that more than a third of the exercises (40%) appeared to reproduce or exacerbate some of the physical or biomechanical demands of VDT work, and that one out of seven exercises posed one or more safety hazards. The majority of these safety hazards were posed by the lower back/hip and knee/lower leg exercises. More than half (60%) of the back/hip exercises, and nearly half (45%) of the shoulder exercises, replicated the physical demands of VDT work, primarily through further stretching of already overstretched muscles of the spine and upper back.

Because the literature shows that musculoskeletal discomfort in VDT/clerical work is particularly acute for the back, neck and shoulder regions[27-29] it is especially important that exercises for these regions satisfy basic design requirements facilitating their performance in the office environment. The present findings are not very promising in this regard. Many of the shoulder and back exercises were highly conspicuous and disruptive of the work process, and thus may meet with resistance by workers. More worrying was the finding that more than a third of the back exercises appeared unsafe to perform, and a sizable number of the neck, shoulder and back exercises (36–60%) appeared to exacerbate, rather than counteract, the physical/biomechanical stresses of VDT work. Apparently, the development of many of these exercises has proceeded without sufficient appreciation for office biomechanical and safety concerns.

While usability and safety criteria should be considered when designing an exercise programme for VDT users, to be fully effective the exercises must additionally combat the full range of musculoskeletal stressors encountered in VDT work. These stressors, and thus the best combination of exercises, will vary to some extent according to the type of task performed. Table 1 was designed to present the results of our analysis in a manner which facilitates the selection of individual exercises for an exercise programme for VDT users. Following an analysis of the task to determine the muscles stressed by task demands, the "muscle groups" and "anatomical structures" columns of Table 1 can be consulted to select exercises to counteract these stressors. For example, Figure 2 illustrates a posture often assumed during VDT work. This posture results in chronically tensed muscles in the shoulders (ie, scapular elevators), forearms (ie, forearm flexors) and chest (ie, anterior thoracic muscles), as well as overstretched muscles of the back (ie, lumbar, thoracic and cervical regions). Table 1 can be consulted to identify exercises which stretch the chronically tensed muscles in the shoulders, forearms and chest, or contract the chronically stretched muscles of the back.

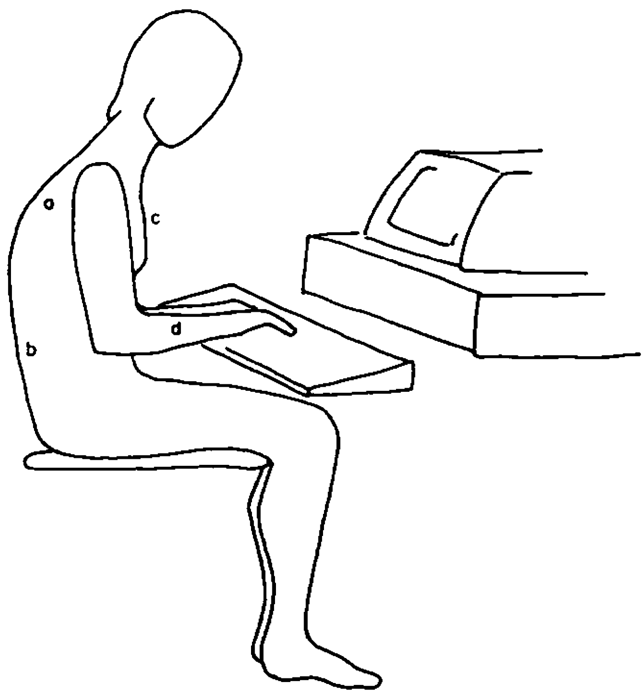

Figure 2 Muscle groups commonly requiring relaxation or activation after periods of continuous VDT work. (a) Chronically tensed scapular elevators require stretching and relaxation. (b) Spinal extensors of the lumbar, thoracic and cervical regions are overstretched and require activation. (c) Muscles of the anterior thoracic region are shortened and require stretching. (d) Forearm flexors are chronically tensed and shortened, and require stretching and relaxation

Regardless of the specific musculoskeletal stressors imposed by a particular VDT task, there are 'generic' stressors common to most VDT work (ie, constrained postures which impart static loads to the neck, back, shoulders and upper extremities, and which impair venous return from the lower extremities). To counteract these generic stressors, any exercise programme for VDT users should include the following components:

1 stretching of chronically shortened and tensed muscles to improve flexibility and circulation, and to reduce muscle fatigue;

2 mobilization of the spine to help relieve stress on the lower back muscles and reduce compressive forces at intervertebral discs;

3 strengthening or contraction of chronically stretched and weakened muscles to increase resistance to fatigue and discomfort, and to promote better posture;

4 improvement of venous return from lower extremities.

The exercise programmes evaluated here focused primarily on the first of these components (stretching/relaxation), and often failed to address the remainder adequately. There is some evidence that strengthening exercises may be more useful than flexibility/relaxation exercises in preventing musculoskeletal discomfort in VDT users[30]. However, such exercises are likely to be far more intrusive and demanding than flexibility or relaxation exercises, and require special employer-designated breaks and exercise areas.

Acknowledgements

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References

1 **World Health Organization** *Visual display terminals and workers' health* Geneva (1987)
2 **Dainoff, M and Dainoff, M** *People and productivity* Holt, Rinehart and Winston of Canada (1986)
3 **Sauter, S, Dainoff, M and Smith, M** *Promoting health and productivity in the computerized office: Models of successful ergonomic interventions* Taylor & Francis (1991)
4 **American National Standards Institute** *American National Standard for human factors engineering of visual display terminal workstations* Human Factors Society (1988)
5 **Grandjean, E** *Ergonomics in computerized offices* Taylor & Francis (1987)
6 **IBM** *Human factors of workstations with visual displays* International Business Machines Corporation (1984)
7 **Sauter, S, Chapman, L and Knutson, S** *Improving VDT work* The Report Store (1986)
8 **Winkel, J** 'On the significance of physical activity in sedentary work' in **Knave, B and Wideback, P-G (eds)** *Work with display units 86* Elsevier Science Publishers (1987) pp 229–236
9 **Schleifer, L and Amick, B** 'System response time and method of pay: stress effects in computer-based tasks' *Int J Hum Comput Interact* Vol 1 (1989) pp 23–39
10 **Zwahlen, H, Hartman, A and Kothari, N** 'Effects of rest breaks in continuous VDT work on visual and musculoskeletal comfort/discomfort and on performance' in **Salvendy, G (ed)** *Human–computer interaction* Elsevier Science Publishers (1984) pp 315–319
11 **Austin, D** *Tone up at the terminals: an exercise guide for computer and word processing operators* Verbatim Corp (1984)
12 **Australian National University** *Additional guidelines for the use of visual display units and other screen based equipment* University Circular No 1206 (1984)
13 **Australian Occupational Safety and Health Unit** *Occupational strain – don't risk it* 2nd edn, The Australian National University (1987)
14 **Dahl, B** *Bedre Med Edb, Manual* VIFI Munksgaard (1986)
15 **Emanuel, J and Glonek, R** *Microscope operations: recommendations for workplace layout and fatigue reduction* Tech. Report, Arizona (1974)
16 **Gore, A and Tasker, D** *Pause gymnastics: Improving comfort and health at work* CCH Australia Limited (1986)
17 **Joyce, M and Peterson, M** *Dataspan: ergonomic skills training* The Joyce Institute (1985)
18 **Joyce, M and Peterson, M** *Instructor's manual* The Joyce Institute (1985)
19 **Joyce, M and Peterson, M** *Training handbook* The Joyce Institute (1985)
20 **Krames Communications** *Working with VDTs* (1984)
21 **Krames Communications** *Fitness at the terminal: comfort tips for computer users* (1986)
22 **Lacy, J** *VDT-user guidelines: banishing headache, eyestrain, and a host of other problems* CRT Services Inc. (1987)
23 **Lee, K and Humphrey, L** 'Comparison of the relative effectiveness of ergonomic design and physical exercise' *Proc 9th Cong Int Ergonomics Assoc* Bournemouth, England (1985) pp 556–558
24 **Lee, K and Waikar, A** 'Comparison of frequency and amplitude analysis in the physical stress study of VDT operators' *Proc Int Sci Conf Work with Display Units* Stockholm (1986) pp 507–510
25 **Los Angeles Times** *Protecting your health with safe and efficient computer terminal use, Los Angeles Times* internal publication (1989)
26 **Pragier, E** *Exercises for office workers* Development Sub-Section, Melbourne Central Office (1985)
27 **Evans, J** 'Women, men, VDU work and health: A questionnaire survey of British VDU operators' *Work and Stress* Vol 1 (1987) pp 271–283
28 **Hagberg, M and Wegman, D** 'Prevalence rates and odds ratios of neck–shoulder diseases in different occupational groups' *Br J Ind Med* Vol 44 (1987) pp 607–610
29 **Rossignol, A, Morse, E, Summers, V and Pagnotto, L** 'Video display terminal use and reported health symptoms among Massachusetts clerical workers' *J Occup Med* Vol 29 (1987) pp 112–118
30 **Dyrssen, T, Paasikivi, J and Svendenkrans M** 'Beneficial exercise programme for office workers with shoulder and neck compaints' Paper presented at Second Int Sci Conf on Work with Display Units, Montreal (11–14 September (1989) pp 1–21

Management of Upper Extremity Cumulative Trauma Disorders

by Thomas R. Hales, MD, and Patricia K. Bertsche, MPH, RN, COHN

Cumulative trauma disorders (CTDs) is an umbrella term describing specific diagnoses of the musculoskeletal system with a common etiology. The specific diagnoses involve damage to the tendons, tendon sheaths, muscles, joints, blood vessels, and peripheral nerves of the upper extremities (Mandel, 1987; Putz-Anderson, 1988; Travers, 1988) (Table 1). Other terms used to describe these disorders include "repetitive motion syndrome," "repetitive strain injury," and "overuse syndrome." These other terms imply that repetitive work is the sole etiology.

Vibrating tools, forceful motions, and motions in awkward or extreme postures are three other important ergonomic hazards proven to cause these disorders (Armstrong, 1982; Arndt, 1987; Blair, 1987; Punnett, 1985; Rothflesch, 1978; Silverstein, 1986; Stock, 1991). Because of these other ergonomic hazards, the authors' preferred term is CTDs.

The most effective means of preventing CTDs, and the primary focus of any ergonomic program, is the development of engineering controls for identified ergonomic hazards. In some instances, however, the application of engineering controls is not feasible due to economic considerations. When engineering controls are not feasible, or until proven effective controls can be installed, other aspects of an ergonomic program—administrative and medical management controls—need implementation. This article focuses on the medical management of CTDs.

The most effective means of preventing CTDs is the development of engineering controls for identified ergonomic hazards.

The medical management of CTDs is not simply the recognition, evaluation, and treatment of CTDs. Other elements critical to a successful medical management program include CTD surveillance, conditioning and rehabilitation programs, and familiarity with OSHA recordkeeping requirements. This article is a practical guideline to assist health and safety professionals, employers, and union health and safety representatives to develop, assess, or modify their medical management program for CTDs.

HEALTH CARE PROVIDERS

The medical management program should be supervised by an occupational health nurse or occupational medicine physician. These individuals should have training in early recognition, evaluation, treatment, rehabilitation, and prevention of CTDs, in addition to the principles of ergonomics, and OSHA recordkeeping requirements. Health care providers (HCPs) working with the medical or nursing director also should be knowledgeable in these topics and be available on site during all shifts. Where such personnel are not employed full time, the part time employment of appropriately trained HCPs is recommended.

COMPONENTS OF A MEDICAL MANAGEMENT PROGRAM

Workplace Walkthrough

The health care provider should conduct a workplace walkthrough every month or whenever a particular job task changes. This walkthrough accomplishes many things. It allows the HCP to: maintain close contact with employees; identify potential light duty jobs; observe individual work practices; and remain knowledgeable about operations described to them by employees.

Ergonomic Classification of Jobs

The employee health department should have a list describing the various ergonomic hazards found on each job within the facility. This list can be used to identify jobs for employees with upper extremity CTDs requiring restricted or light duty, and can assist in the development of a job rotation program. The personnel in the employee health department are valuable assets in the development of this job classification because they have contact with symptomatic workers and information generated from the walkthrough and symptoms survey (see next section). This list is reviewed and revised periodically to reflect any changes in ergonomic hazards of any particular job.

CTD Surveillance

Engineering controls that reduce or eliminate ergonomic hazards are needed to prevent CTDs. Identifying and prioritizing areas for intervention are critical. The personnel in the employee health department can assist in this effort by using passive or active surveillance systems to identify high risk departments, production lines, or jobs.

Passive surveillance systems use existing data sources, such as the OSHA 200 logs, and workers' compensation claims to find high risk areas. High risk areas are not simply the areas with the most cases of CTDs, but rather the areas with the highest incidence rate of CTDs. The incidence rate is the number of CTD cases (numerator) over the number of people at risk for a given time period (denominator).

Using the OSHA 200 logs as an example, the numerator is the number of "7f" cases (disorders due to repeated trauma) for a given time period. The denominator is the number of employees in that particular department or job for the same time period. This method can identify high risk departments, production lines, or jobs, and is usually expressed as cases per 100 or 10,000 full time workers per year (U.S. Department of Labor, 1986).

Although attractive due to their low cost, passive surveillance programs have limitations that can hamper identification of high risk areas. These include underreporting; disease misclassification; and exposure misclassification. Underreporting can result from any of the following: symptomatic employees not seeking first aid care (macho workers, ignorance that the condition could be work related, or fear of employer retaliation); restricted or no access to first aid or employee health departments; or differing interpretation about when a CTD case is to be recorded on the OSHA 200 log.

Disease misclassification occurs when a CTD is recorded as an injury rather than as a "disorder due to repeated trauma." Exposure misclassification can occur when employees use a general term to describe their job title. For example, an employee in the meatpacking industry may report the job title "cutter" in a plant with 20 distinct cutting positions. Each one of these cutting jobs may be associated with very different ergonomic hazards, and to identify high risk jobs the HCP must know, specifically, at which cutting position the employee is working.

Because of the problems with passive surveillance systems, the HCP should consider conducting *active surveillance*, a symptom survey of all employees. The symptom survey questionnaire should be short and clear and use body diagrams to identify symptomatic areas (see Figure 1). The symptom survey should be anonymous unless the HCP can assure employees of strict confidentiality.

The primary purpose of the symptom survey is to identify high risk jobs for intervention. However, the information can be used for other purposes, including: monitoring the effectiveness of ergonomic interventions; finding unrecognized ergonomic hazards; and, if conducted in a confidential manner, serving a triage function for employees needing health care evaluations.

If the symptom survey is conducted anonymously, groups of employees can be identified for evaluations. This point deserves emphasis.

TABLE 1
Specific Diagnoses Referred to as Cumulative Trauma Disorders (CTDs)

Tendon Related Disorders

Tendonitis
Tenosynovitis
Stenosing tenosynovitis of the fingers (trigger finger)
Stenosing tenosynovitis of the thumb (DeQuervain's)
Peritendonitis (strain)
Ganglion cyst
Lateral epicondylitis (tennis elbow)
Medial epicondylitis (golfer's elbow)
Bicipital tendonitis
Rotator cuff tendonitis

Peripheral Nerve Entrapment

Carpal tunnel syndrome
Guyon tunnel syndrome
Radial tunnel syndrome
Pronator teres syndrome
Cubital tunnel syndrome

Vascular

Hand-arm vibration syndrome (Raynaud's phenomena)
Ulnar artery thrombosis

Neurovascular

Thoracic outlet syndrome

Muscular

Focal dystonia
Fibromyositis
Tension neck syndrome
Myositis

Joint/Joint Capsule

Osteoarthritis
Bursitis
Synovitis

Symptoms Survey: *Ergonomics Program*

DATE____/____/____

______	______	________	____________________
Plant	Dept #	Job #	Job Name

______	____________	____________	_____years_____months
Shift	Supervisor	Hours worked/week	Time on THIS job

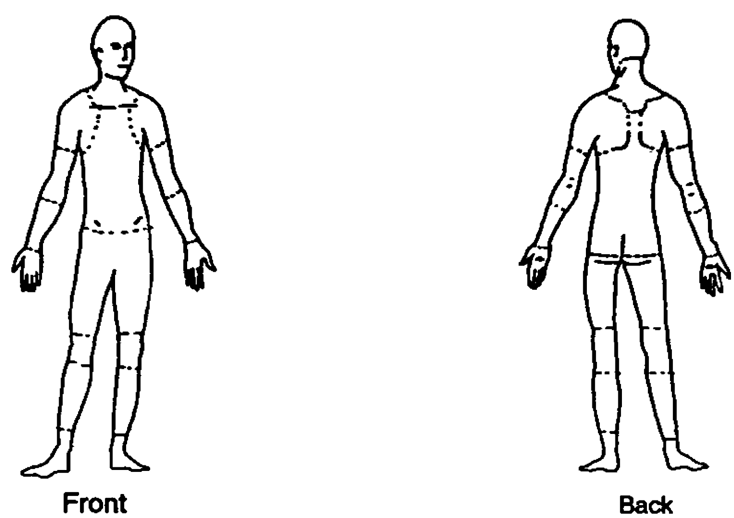
Other jobs you have done in the last year (for more than 2 weeks)

______	______	________	____________	_____months_____weeks
Plant	Dept #	Job #	Job Name	Time on THIS job
______	______	________	____________	_____months_____weeks
Plant	Dept #	Job #	Job Name	Time on THIS job

(If more than 2 jobs, include those you worked on the most)

Have you had any pain or discomfort during the last year?
❑ Yes ❑ No (If NO, stop here)

If YES, carefully shade in the area of the drawing which bothers you the MOST.



(Continued)

Figure 1: Symptoms survey checklist.

(Complete a separate page for each area that bothers you)

Check Area: ❑ Neck ❑ Shoulder ❑ Elbow/Forearm ❑ Hand/Wrist ❑ Fingers
❑ Upper Back ❑ Low Back ❑ Thigh/Knee ❑ Low Leg ❑ Ankle/Foot

1. Please put a check by the word(s) that best describe your problem

❑ Aching
❑ Burning
❑ Cramping
❑ Loss of Color
❑ Numbness (asleep)
❑ Pain
❑ Swelling
❑ Stiffness
❑ Tingling
❑ Weakness
❑ Other

2. When did you first notice the problem? ____________(month) ____________(year)

3. How long does each episode last? (Mark an X along the line)

_________/_________/_________/_________/___________
1 hour 1 day 1 week 1 month 6 months

4. How many separate episodes have you had in the last year?________________________

5. What do you think caused the problem?____

____

6. Have you had this problem in the last 7 days? ❑ Yes ❑ No

7. How would you rate this problem (mark an X on the line)
NOW

____
None Unbearable

When it was the WORST

____
None Unbearable

8. Have you had medical treatment for this problem? ❑ Yes ❑ No

8a. If NO, why not____

8b. If YES, where did you receive treament?________________________________

1. Company Medical ❑ Times in past year______
2. Personal doctor ❑ Times in past year______
3. Other ❑ Times in past year______

8c. If YES, did the treatment help? ❑ Yes ❑ No

9. How much time have you lost in the last year because of this problem?______days

10. How many days in the last year were you on restricted or light duty because of this problem?
______days

11. Please comment on what you think would improve your symptoms

____

____

____

____

Unless the HCP can assure employees of strict confidentiality, the survey should be anonymous. Any real or perceived violation of this ethical code can render the information invalid.

CTD Evaluation

The main objective of CTD surveillance is to identify jobs needing intervention to eliminate the ergonomic hazards. The purpose of CTD evaluation, on the other hand, is to identify individuals with mild CTDs, allowing early treatment to limit the severity of the condition.

Frequency. The HCP should perform a CTD evaluation of employees assigned to jobs with known ergonomic hazards or areas found to have CTD problems by the surveillance system. These evaluations should occur: prior to starting a high risk job (preplacement or baseline evaluation); following the conditioning period (post-conditioning evaluation); and periodically (approximately every 3 years).

Preplacement or Baseline Evaluation: The purpose of a preplacement upper extremity musculoskeletal evaluation is to establish a base against which changes in an individual's health status can be measured. It is not to be used as a preemployment screening program precluding certain individuals from employment. Not only would such determinations be discriminatory, but no screening tests or examinations have been validated as predictive procedures for determining which workers will develop CTDs.

Post-conditioning Period Evaluation: New and transferred employees performing jobs with known ergonomic hazards should be given a 4 to 6 week break-in period to condition their muscle-tendon groups. This means working at reduced speed with more frequent breaks, and is also known as "work hardening" (Flinn-Wagner, 1990). Following this work hardening or conditioning period the employees should have a health evaluation to determine if conditioning of the muscle-tendon groups has been successful.

Employees typically report transient soreness or fatigue during the conditioning period. However, these symptoms should resolve within a few weeks, consistent with normal adaptation to the job. If the symptoms persist they may represent the early stages of a CTD. Work hardening programs of shorter duration also should be available to employees returning to work from a vacation lasting for more than 1 week.

Periodic Evaluation: Employees working on jobs with ergonomic hazards should have a CTD evaluation approximately every 3 years. The purpose of this periodic evaluation is to identify employees with CTDs who, for whatever reason, do not report their symptoms to the employee health department.

Content. The CTD evaluation should consist of a medical and occupational history and a brief noninvasive physical examination (inspection, palpation, range of motion testing, and various maneuvers).

The *history* should elicit the location, duration, frequency, intensity, and onset of discomfort (pain, swelling, aching, tingling, numbness, burning, or stiffness). Note if the symptoms started before or after employment at that facility, if the symptoms are exacerbated by job tasks, if any previous injuries or fractures to that joint area occurred, if any recreational activities or hobbies exacerbate the condition, and if any medical conditions known to be associated with carpal tunnel syndrome are present (Table 2).

The *physical examination* of the upper extremities includes inspection for signs of inflammation (redness, swelling), ganglion cysts, or deformities. Palpation can identify areas of discomfort, as well as warmth, the third sign of inflammation. Passive, active, and resisted range of motion maneuvers can again elicit areas of discomfort in addition to crepitus and stenosis.

Other maneuvers include Tinel's test of the median and ulnar nerves, Phalen's test, and Finkelstein's test.

TABLE 2
Conditions Associated with Carpal Tunnel Syndrome*

Endocrine Disorders
Diabetes mellitus, pregnancy, use of estrogens or oral contraceptives, acromegaly, myxedema

Rheumatic Disorders
Rheumatoid arthritis, systemic lupus erythematosus, scleroderma, polymyalgia rheumatica, eosinophilic fasciitis, gout, osteoarthritis

Cardiac Disorders
Congestive heart failure, vascular shunts

Blood Disorders
Amyloidosis, hemophilia

Renal Disorders
Uremia

Infectious Disorders
Tuberculosis

Traumatic Disorders
Previous fracture of the carpal bones

Tumors: Benign
Gangliomas, lipomas

Tumors: Malignant
Multiple myeloma

**Adapted from Leach, 1968; Spinner, 1989*

Remember that CTDs can exist without external manifestations of inflammation (Wigley, 1990).

Tinel's test of the median nerve consists of tapping the median nerve as it passes through the carpal canal (Mossman, 1987). A positive response is pain, or paresthesia in digits two and three (Katz, 1990). Tinel's test of the ulnar nerve consists of tapping the ulnar nerve as it passes through Guyon's canal. A positive response is pain or paresthesia in digits 4 or 5.

Phalen's test is flexing both wrists 90° with the dorsal aspect of the hands held in apposition for 60 seconds (Phalen, 1966). A positive response is pain or paresthesia in digits 2 and 3 (Katz, 1990; Phalen, 1966).

Finkelstein's test is ulnar deviation of the hand with the thumb flexed against the palm and the fingers flexed over the thumb (Finkelstein, 1930). A positive response is severe pain at the radial styloid due to stretching of the abductor pollicis longus and extensor pollicis brevis (Finkelstein, 1930; Labidus, 1953). Trigger finger is the locking of a finger in flexion or a palpable tendon sheath ganglion (Labidus, 1953).

Collecting and recording this information in a uniform manner is imperative. Figure 2 provides one example of such a recording form.

Evaluation of Symptomatic Employees

Individuals presenting to the employee health department with upper extremity symptoms, or identified as having problems by the confidential symptom survey, also should have a CTD evaluation. The content of this evaluation obviously will be dictated by the intensity and location of the symptoms. However, the physical examination described above (Figure 2) could be used as a framework.

Treatment of CTDs

After performing the above evaluation, the HCP must now use the information to make an assessment and to formulate a treatment plan. Figure 3 provides the HCP with a CTD medical management algorithm. This algorithm is not meant to dictate practice, but rather to outline a therapeutic approach based on the history and physical examination.

The main message from this algorithm is not its specifics. Rather, symptomatic employees need follow up to determine the effectiveness of the prescribed treatments; employees with severe symptoms, positive physical findings, or disorders resistant to treatment need to be referred to a physician for further evaluation; and conservative therapy deserves an adequate trial before surgical intervention is contemplated (in most cases this should be at least 6 months).

Conservative therapy involves: 1) the application of heat or cold, 2) non-steroidal antiinflammatory agents, 3) physical therapy, and 4) splints.

Cold is used to treat tendon and joint related disorders for pain relief, and swelling reduction (Simon, 1986). Cold decreases the inflammation of CTDs even if no external signs of inflammation are present (redness, swelling, warmth). *Heat* can be used for muscle related disorders (tension neck syndrome or muscle spasms). Heat is inappropriate for employees with tendon related disorders, and cold is inappropriate for employees with vascular related CTDs such as hand-arm vibration syndrome (Nanneman, 1991; Putz-Anderson, 1988).

Non-steroidal antiinflammatory agents may be helpful in reducing soft tissue inflammation; however, their gastrointestinal and renal side effects limit their usefulness (Simon, 1980).

Physical therapy may be a useful component to a CTD treatment or rehabilitation program (King, 1990). Stretching exercises should be performed under the supervision of an occupational health nurse or physical therapist to insure the exercises are performed properly and do not aggravate the condition. Once the employee can perform these exercises properly, supervision is needed only intermittently.

In-plant stretching exercises two or three times a day have been suggested as a method of preventing CTDs in asymptomatic employees (Allers, 1989). The effectiveness of such a program is questionable for three reasons. Exercises that involve stressful or extreme range of motions can exacerbate conditions in individuals who have not reported their CTDs to the employee health department. These exercises typically will reduce the rest periods allowed employees. A controlled study found these stretching programs to be ineffective (Silverstein, 1988).

Off the job or night *splints* may be helpful for hand and wrist CTDs. These splints should maintain the joint in a neutral posture and will discourage employees from performing activities that exacerbate their CTDs (Kessler, 1986; Spinner, 1989). The use of splints on the job should be discouraged unless the occupational health nurse or ergonomist has determined the job does not require wrist bending. Employees who struggle to perform a task requiring wrist deviation with a splint designed to prevent wrist deviation can exacerbate symptoms in the wrist due to the increased force needed to overcome the splint. It also may cause other joint areas (elbows or shoulders) to become symptomatic as technique is altered (Kessler, 1986; Putz-Anderson, 1988).

The effectiveness of hot wax treatments and constrictive wrist wraps has not been established. Effectiveness of vitamin B6 to treat or prevent carpal tunnel syndrome has been disproven and may actually be neurotoxic in prescribed doses (Amadio, 1987).

If initial treatment of the CTD does not result in improvement or resolution of the symptoms, employees must be taken off the jobs causing the problem. They can be transferred to a restricted or light duty job, or if such a job is not available, they should receive time off work. The intent of light duty work is to provide the worker with an alternate job that has minimum exposure to known risk factors for CTDs.

Only after an adequate trial of conservative therapy and time away from the job causing the problem should surgical intervention be considered. In most cases this should involve at least 6 months of conservative therapy. Surgical intervention can be appropriate for carpal tunnel syndrome and trigger finger.

While carpal tunnel release surgery has been reported to be 80% to 90% effective in decreasing or relieving the pain, its effectiveness in re-

Name: ______________________________ Current Job: ____________________
Examiner: ______________________________ Date: ___/___/___

Discomfort Scale: 1=no discomfort, 2=mild, 3=moderate, 4=severe, 5=worst ever

NECK:

	Right	Left	
Inspection: Inflammation (red, swollen, warm)		___Yes	___No
Palpation:	Right	Left	
Trapezius Trigger Point	___	___	
Trapezius Spasm	___	___	
Manevuers:			
Resisted Flexion	___	___	
Resisted Extension	___	___	
Resisted Rotation	___	___	

SHOULDER

	Right	Left	
Inspection: Acromium Inflammation?		___Yes(R or L)	___No
Maneuvers:	Right	Left	
Passive Abduction	___	___	
Active Abduction	___	___	
Resisted Abduction	___	___	
Deltoid Palpation	___	___	

ELBOW

	Right	Left	
Inspection: Olecranon Inflammation:		___Yes(R or L)	___No
Palpation:	Right	Left	
Medial Epicondyle	___	___	
Lateral Epicondyle	___	___	

FOREARM

	Right	Left	
Inspection: Forearm Inflammation?		___Yes(R or L)	___No
Maneuvers:	Right	Left	
Passive Wrist Flexion	___	___	
Passive Wrist Extension	___	___	
Resisted Wrist Flexion	___	___	
Resisted Wrist Extention	___	___	
Resisted Finger Flexion	___	___	
Resisted Finger Extention	___	___	
3rd digit resisted Extention	___	___	

WRIST

	Right	Left	
Inspection: Inflammation		___Yes(R or L)	___No
Extensor ganglion cyst		___Yes(R or L)	___No
Flexor ganglion cyst		___Yes(R or L)	___No
Maneuvers:	Right	Left	
Guyon Tinel's	___	___	
Carpal Tinel's	___	___	
Phalen's	___	___	

HANDS AND FINGERS

	Right	Left	
Inspection: Inflammation		___Yes(R or L)	___No
Maneuvers:	Right	Left	
Trigger Finger	___	___	
Finkelstein's	___	___	

Figure 2: Physical examination recording form for health care providers.

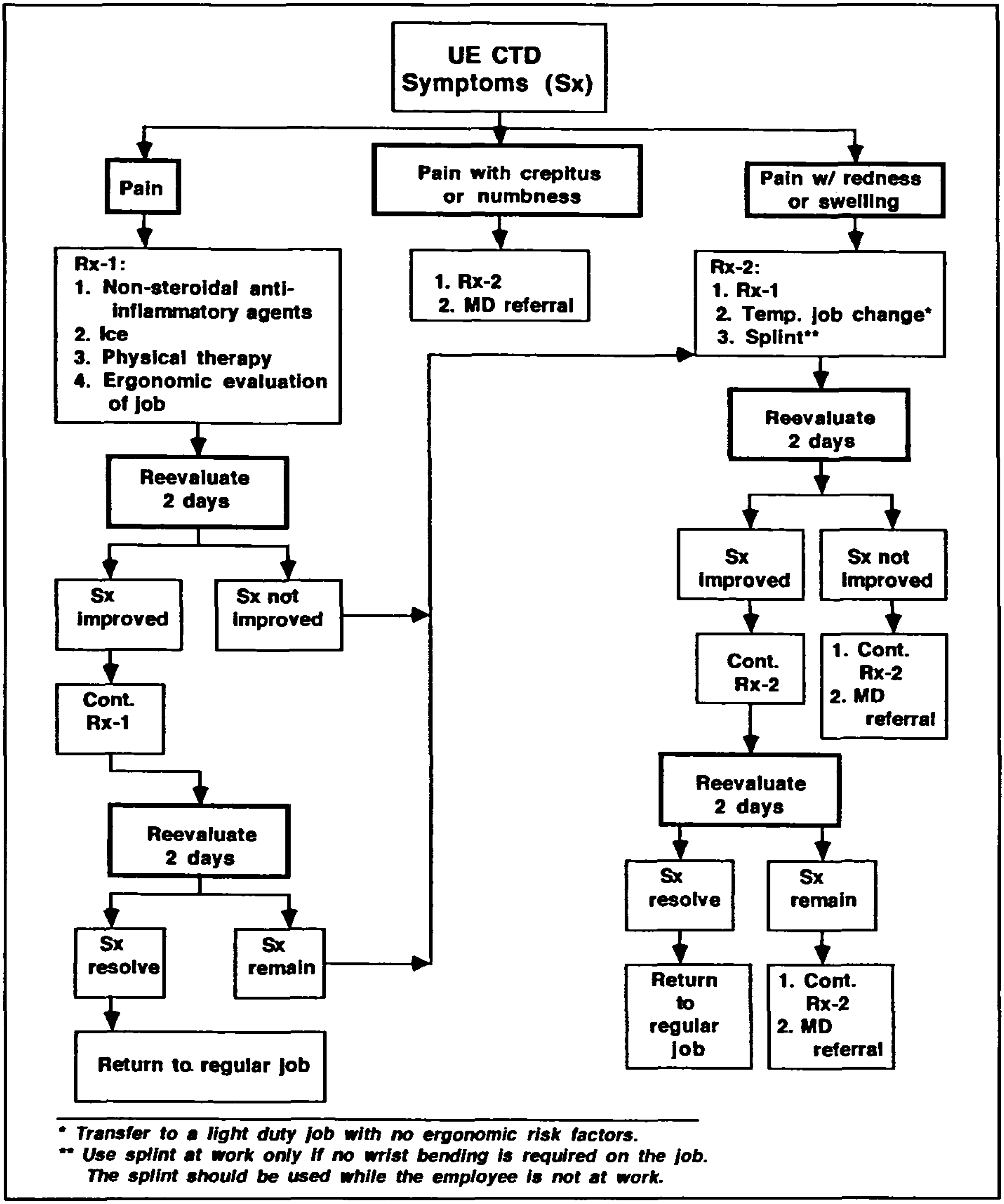


Figure 3: Upper extremity cumulative trauma disorders algorithm.

turning employees to their original jobs is 40% to 50% at best (Jaeger, S.H., personal communication, 1990). All employees scheduled for carpal tunnel release surgery should have: 1) their treatment program reviewed to assure that conservative therapy has failed, and 2) a second opinion to corroborate the need for surgery.

Employee Education

Detection of CTDs prior to the development of a severe, disabling condition should lead to a rapid and complete recovery. To facilitate the early evaluation of CTDs, all employees, including supervisors and other plant management personnel, should be educated on the causes and the early symptoms and signs of CTDs. Encouraging employees to report symptoms to their supervisor with subsequent referral to the employee health department allows for timely and appropriate evaluation and treatment.

It is important to avoid any potential disincentives for employee reporting, such as limits on the number of visits to the health unit, monetary bonuses for not reporting to the health unit, or fear of discrimination or reprisal by employers against employees who report symptoms. This education process should occur during the orientation or training period and be reinforced periodically.

OSHA Form 200 Recording

The Department of Labor has issued guidelines that provide official interpretations for recording and reporting occupational injuries and illnesses (U.S. Department of Labor, 1986). These guidelines provide supplemental instructions for the OSHA recordkeeping forms (OSHA Forms 200, 101, and 200-S) and should be available in every employee health department. HCPs should be responsible for entering the appropriate information onto the OSHA forms; therefore, they should be aware of OSHA's recordkeeping requirements.

Occupational Illnesses. All work related illnesses must be recorded on the OSHA 200 form, even if the condition is in an early stage of development. Diagnosis of these conditions may be made by a physician, registered nurse, or by a person who, by training or experience, is capable of making such a determination.

If the condition is "diagnosed or recognized" as work related, the case must be entered on the OSHA 200 form within 6 work days after detection. CTDs should be recorded on the OSHA 200 form as an occupational illness under the "7f" column ("disorders associated with repeated trauma"). These are disorders caused, aggravated, or precipitated by repeated motion, vibration, or pressure. To be recordable a CTD must be diagnosed, and the CTD must be work related.

CTD Diagnosis: A CTD is diagnosed when there are a) objective findings on physical examination, ***or*** b) subjective symptoms with resulting action.

Examples of positive physical findings include positive maneuvers (Tinel's, Phalen's, or Finkelstein's tests); or signs of inflammation (swelling, or redness); or joint deformity; or loss of motion.

Examples of subjective symptoms include pain, numbness, tingling, aching, stiffness, or burning. Resulting action includes at least one of the following:

- Medical treatment (including self administered treatment when made available to employees by their employer); or
- Lost workdays (includes restricted work activity); or
- Transfer/rotation to another job.

Work Related: The CTD is work related if the exposure at work either caused or contributed to the onset of symptoms or aggravated existing symptoms to the point that they meet OSHA recordability criteria. Examples of work tasks or working conditions that are likely to elicit a work related CTD include:

- Repetitive and/or prolonged physical activities.
- Forceful exertions, usually with the hands (including tools requiring pinching or gripping).
- Awkward postures of the upper body, including reaching above the shoulders or behind the back, and angulation of the wrists to perform tasks.
- Localized contact areas between the work or work station and the worker's body; i.e., contact with surfaces or edges.
- Excessive vibration from power tools.
- Cold temperatures.

Other Considerations: A case is considered to be complete once signs and symptoms resolve completely. If signs or symptoms recur, a new case is established and thus must be recorded as a new case on the OSHA 200 form. Furthermore, failure of the worker to return for care after 30 days indicates symptom resolution. Any visit to an HCP for similar complaints after the 30 day interval implies reinjury and represents a new case.

It is essential that required data, including job identification, be consistently, fully, and accurately recorded on the OSHA 200 form. "Job identification" will include the appropriate job title for "Occupation" and the appropriate organizational unit for "Department" on the OSHA 200.

Health care providers and others should contact the OSHA area or regional office, or state occupational safety and health agency serving their area with questions about OSHA recordkeeping.

Program Evaluation

The nursing or medical director responsible for the CTD medical management program should review the program periodically to evaluate the effectiveness of the various components. Ineffective components should be modified to achieve their stated objective.

CONCLUSION

CTDs are painful conditions with the potential to result in crippling disorders. The direct costs (medical and workers' compensation) and indirect costs (lost productivity and expense incurred training new workers) can be staggering to employers. The medical management program described in this article should prevent and/or limit the severity of these disorders, resulting in a healthier, more productive workplace.

REFERENCES

Allers, A. (1989, August). Workplace prevention program cut cost of illness and injury. Pre-work flexibility stretching reduces employee muscular injury and company health-care cost. *Occupational Health & Safety, 58*(8), 26-29.

Amadio, P.C. (1987). Pyridoxine as an adjunct in the treatment of carpal tunnel syndrome. *Journal of Hand Surgery, 12A*, 384-391.

Armstrong, T.J., Foulke, J.A., Joseph, B.S., & Goldstein, S.A. (1982). Investigation of cumulative trauma disorders in a poultry plant. *American Industrial Hygiene Association Journal, 43*, 103-116.

Arndt, R. (1987). Work pace, stress, and cumulative trauma disorders. *Journal of Hand Surgery, 12A*(Suppl,5), 850-855.

Blair, S.J., & Bear-Lehman, J. (1987). Editorial comment: Prevention of upper extremity occupational disorders. *Journal of Hand Surgery, 12A*(Suppl,5), 821-822.

Finkelstein, H. (1930). Stenosing tenovaginitis at the radial styloid process. *Journal of Bone and Joint Surgery, 12*, 509.

Flinn-Wagner, S., Mladonicky, A., & Goodman, G. (1990). Characteristics of workers with upper extremity injuries who make a successful transition to work. *Journal of Hand Therapy, 3*(2), 51-55.

Katz, J.N., Larson, M.G., Sabra, A., Krarup, C., Stirrat, C.R., Sethi, R., Eaton, H.M., Fossel, A.H., & Liang, M.H. (1990). The carpal tunnel syndrome: Diagnostic utility of the history and physical examination findings. *Annals of Internal Medicine, 112*, 321-327.

Kessler, F.B. (1986). Complications of the management of carpal tunnel syndrome. *Hand Clinics, 2*(2), 401-406.

King, J.W. (1990). An integration of medicine and industry. *Journal of Hand Therapy, 3*(2), 45-50.

Labidus, P. (1953). Stenosing tenovaginitis.

Upper Extremity CTDs IN SUMMARY

Management of Upper Extremity Cumulative Trauma Disorders. Hales, T.R., & Bertsche, P.K. *AAOHN Journal* 1992; 40(3):118-128.

1. Elements critical to a successful medical management program include cumulative trauma disorder (CTD) surveillance, conditioning and rehabilitation programs, and familiarity with OSHA recordkeeping requirements, in addition to recognition, evaluation, and treatment.

2. Occupational health care providers (HCPs) can identify high risk departments, production lines, or jobs through the passive and/or active surveillance systems.

3. The HCP should perform a CTD evaluation of employees assigned to jobs with known ergonomic hazards or areas found to have CTD problems by the surveillance system. These evaluations should consist of a medical and occupational history, and a physical examination of the upper extremities.

4. The treatment algorithm emphasizes that a) symptomatic employees need follow up to determine the effectiveness of the prescribed treatments, b) employees with severe symptoms, positive physical findings, or disorders resistant to treatment need to be referred to a physician for further evaluation, and c) conservative therapy deserves an adequate trial before surgical intervention is contemplated.

Surgical Clinics of North America, 33, 1317-1347.

Leach, R.E., & Odom, J.A., Jr. (1968). Systemic causes of carpal tunnel syndrome. *Postgraduate Medical Journal, 44,* 127-131.

Mandel, S. (1987). Neurologic syndrome from repetitive trauma at work. *Postgraduate Medicine, 82*(6), 87-92.

Mossman, S.S., & Blau, J.N. (1987). Tinel's sign and the carpal tunnel syndrome. *British Journal of Industrial Medicine, 294,* 680.

Nanneman, D. (1991). Thermal modalities: Heat and cold. Review of physiologic effects with clinical applications. *AAOHN Journal, 39*(2), 70-75.

Phalen, G.S. (1966). The carpal tunnel syndrome. Seventeen years' experience in diagnosis and treatment of 654 hands. *Journal of Bone and Joint Surgery, 48A,* 211-228.

Punnett, L., Robins, J.M., Wegman, D.H., Keyserling, M. (1985). Soft tissue disorders in the upper limbs of female garment workers. *Scandinavian Journal of Work Environments and Health, 11,* 417-425.

Putz-Anderson, V. (1988, April). *Cumulative Trauma Disorders: A Manual for Musculoskeletal Diseases of the Upper Limbs.* London: Taylor and Francis, Ltd.

Rothflesch, S., & Sherman, D. (1978). Carpal tunnel syndrome: Biomechanical aspects of occupational occurrence and implication regarding surgical management. *Orthopaedic Review,* 7(6), 107-109.

Silverstein, B.A., Fine, L.J., & Armstrong, T.J. (1986). Hand wrist cumulative trauma disorders in industry. *British Journal of Industrial Medicine, 43,* 779-784.

Silverstein, B.A., Fine, L.J., & Armstrong, T.J. (1987). Occupational factors and carpal tunnel syndrome. *American Journal of Industrial Medicine, 11,* 343-358.

Silverstein, B.A., Armstrong, T.J., Longmate, A., & Woody, D. (1988). Can in-plant exercises control musculoskeletal symptoms? *Journal of Occupational Medicine, 38,* 922-927.

Simon, L.S., & Mills, J.A. (1980). Drug therapy: Nonsteroidal antiinflammatory drugs (pts 1 and 2). *New England Journal of Medicine, 302,* 1179, 1237.

Simon, H.B. (1986). Current topics in medicine: Sports medicine. In: Rubenstein, E., & Federman, D.D. (eds.). *Scientific American Medicine.* New York, NY: Scientific American Inc., p. 22.

Spinner, R.J., Bachman, J.W., & Amadio, P.C. (1989). The many faces of carpal tunnel syndrome. *Mayo Clinical Proceedings, 64,* 829-836.

Stock, S. (1991). Workplace ergonomic factors and the development of musculoskeletal disorders of the neck and upper limbs: A meta-analysis. *American Journal of Industrial Medicine, 19,* 87-101.

Travers, P.H. (1988). Soft tissue disorders of the upper extremities. *Occupational Medicine: State of the Art Review, Worker Fitness and Risk Evaluations, 3*(2), 271-283.

U.S. Department of Labor, Bureau of Labor Statistics. (1986). Recordkeeping Guidelines for Occupational Injuries and Illnesses. O.M.B. No. 1220-0029.

Wigley, R.D. (1990). Repetitive strain syndrome—fact not fiction. *New Zealand Medical Journal, 103,* 75-76.

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ERGONOMICS AND PREVENTION OF MUSCULOSKELETAL INJURIES

Ergonomic principles can be applied to prevent both overt and cumulative traumas. An example in the overt category is the risk of falling from a ladder, which can be reduced by considering the sizes and mobility of people when deciding how far apart to place a ladder's rungs (250). Cumulative traumas are not the result of single events or stresses; they stem from the repeated performance of certain tasks. Back problems are by far the most common cumulative trauma injuries. Evaluation and redesign of tasks to prevent back injuries is discussed later in this chapter.

Repetitive motion disorders are a type of cumulative trauma associated with repeated, often forceful movements, usually involving the wrist or elbow. Some 20 million workers on assembly lines and in other jobs that require repetitive, strain-producing motions are at increased risk of developing such disorders. Redesigning work stations, equipment, and handtools can significantly reduce the awkward, forceful movements common to many jobs on assembly lines, in food processing, in the garment industry, and in offices. Carpal tunnel syndrome, one of this class of disorders, illustrates the potential for prevention offered by the integration of ergonomics, medical surveillance, and treatment.

Carpal Tunnel Syndrome

A wide variety of workers (see table 7-1), from aircraft assemblers to upholsterers, are among those at risk for carpal tunnel syndrome (CTS), a progressively disabling and painful condition of the hand. Because the musculoskeletal strain from repeatedly flexing the wrist or applying arm-wrist-finger force does not cause observable injuries, it often takes months or years for workers to detect damage.

Table 7-1.—Occupations and Activities Associated With Carpal Tunnel Syndrome

Aircraft assembly	Inspecting
Automobile assembly	Meat processing
Buffing	Metal fabricating
Coke making	Musicians
Electronic assembly	Packaging
Fabric cutting/sewing	Postal workers
Fruit packing	Textile workers
Gardening	Tire and rubber workers
Hay making	Typing
Waitressing	Upholstering
Housekeeping	

SOURCE: (60)

The incidence and prevalence of CTS in the work force is not known. The National Institute for Occupational Safety and Health (567) reports that 15 to 20 percent of workers employed in construction, food preparation, clerical work, production fabrication, and mining are at risk for cumulative trauma disorders. The Bureau of Labor Statistics (603) reports 23,000 occupationally related repetitive motion disorders in 1980, although the number of CTS cases is not specified.

CTS is undoubtedly underreported in aggregate statistics. Research in particular high-risk plants provides some insight into the extent of the problem. In a study at an athletic products plant, 35.8 percent of workers had a compensable repetitive trauma disorder. In some jobs within the plant,

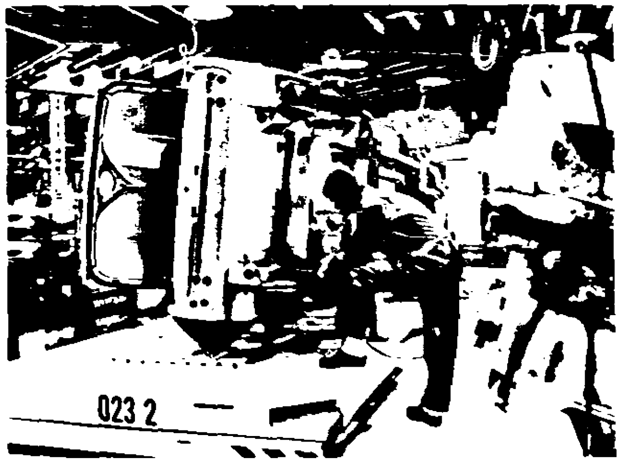



Photo credit: OSHA, Office of Information and Consumer Affairs

Work on an automobile assembly line can involve cramped working positions. A Volvo assembly plant in Kalmar, Sweden, uses "tipper trolleys." These trolleys hold the automobile bodies and can be tipped 90 degrees to allow work on the underside of the car

the rate was as high as 44.1 percent, and carpal tunnel syndrome occurred in 3.4 percent of the workers (21,23). Many industries claim that the incidence of CTS is increasing and is one of their most disabling and costly medical problems (60).

Symptoms

The onset of symptoms of CTS is usually insidious. Frequently, the first complaint is of attacks of painful tingling in one or both hands at night, sufficient to wake the sufferer after a few hours of sleep. Accompanying this is a subjective feeling of uselessness in the fingers, which are sometimes described as feeling swollen. Yet little or no swelling is apparent. As symptoms increase, attacks of tingling may develop during the day, but the associated pain in the arm is much less common than at night. Patients may detect changes in sensation and power to squeeze things but some people suffer severe attacks of pain for many years without developing abnormal neurological signs. Ultimately, in advanced cases, the thenar muscle at the base of the thumb atrophies, and strength is lost.

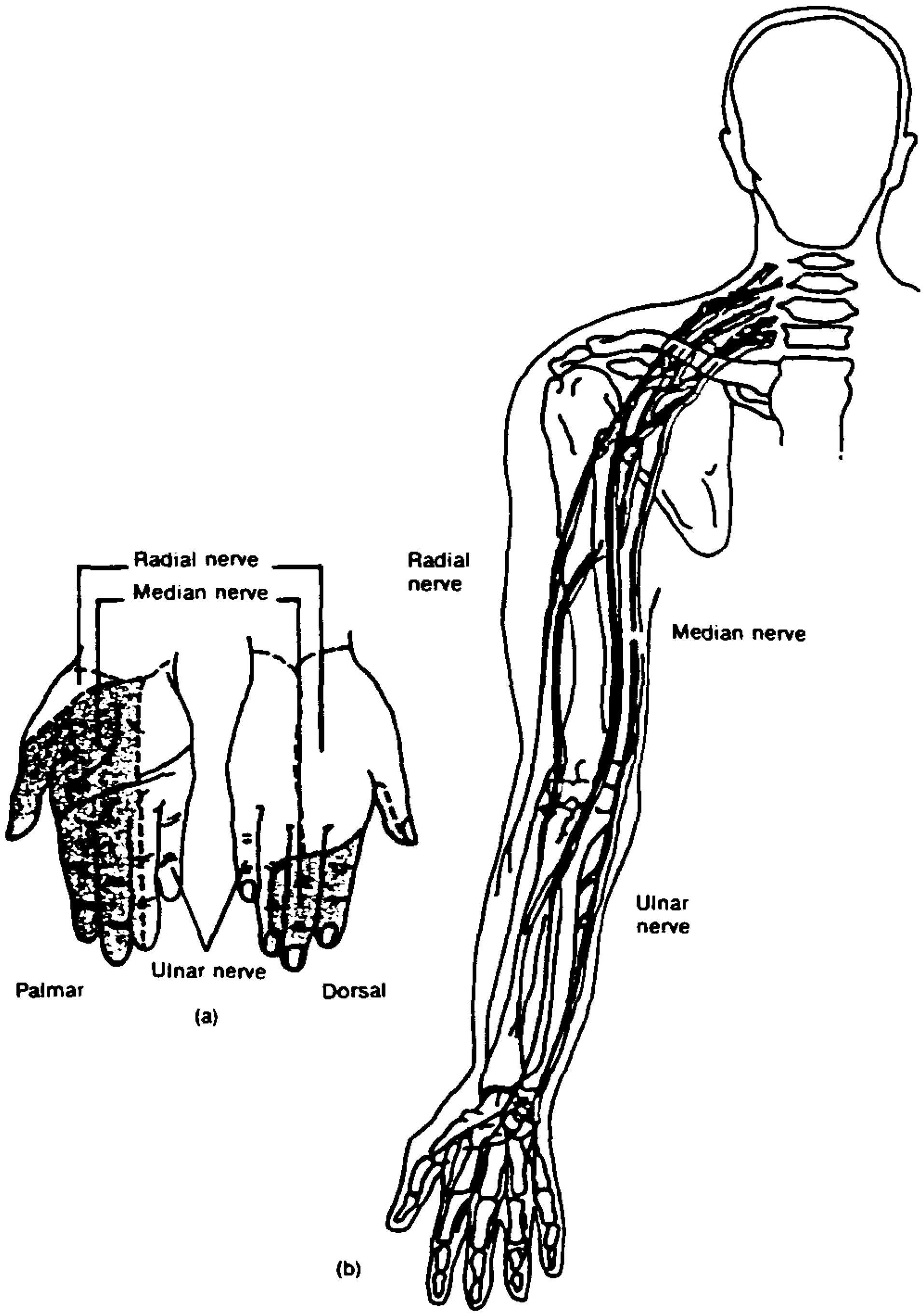
Compression of the median nerve is the immediate cause of CTS. The median nerve comes down the arm, through the wrist, then branches in the hand, supplying the thumb, forefinger, middle finger, and half the ring finger with nerves (fig. 7-3). The carpal tunnel itself, located in the wrist, is formed by the concave arch of the carpal bones and is roofed by the transverse carpal ligament (fig. 7-4). These structures form a rigid compartment through which nine finger tendons and the median nerve must pass. Any compromise of this unyielding space usually compresses the median nerve.

Risk Factors

Repetitive motions, such as those required in many jobs, is one of a number of risk factors for CTS. It is probably the most readily controllable cause, however. Certain diseases, acute trauma, congenital defects, wrist size, pregnancy, oral contraceptive use, and gynecological surgery all may contribute to the likelihood of developing CTS. Overall, the incidence of CTS is higher in women than in men, perhaps because of some of these risk factors.

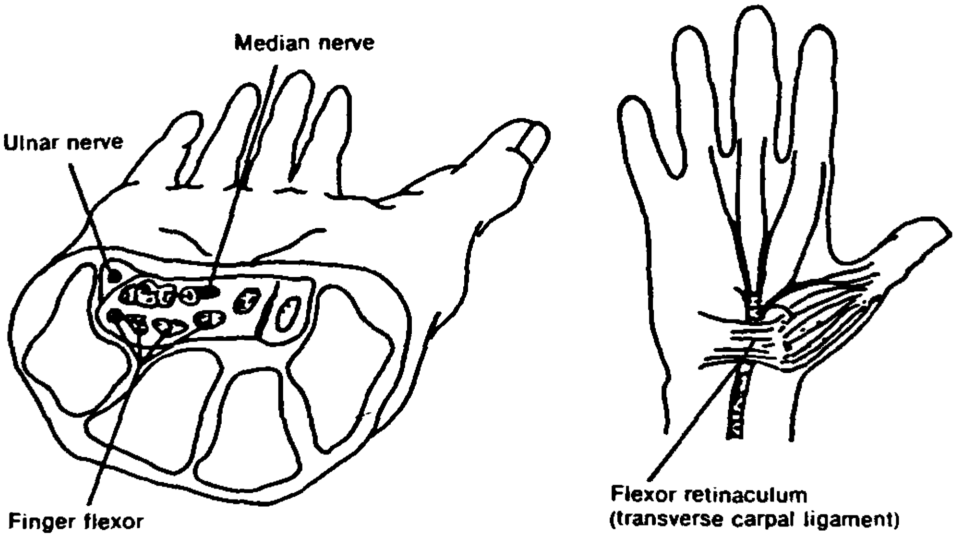
Occupational tasks responsible for the development of CTS include physical exertions with certain hand postures or against certain objects, and exposures to vibration or cold temperatures. Repeated and forceful up-and-down motions of the wrist (flexion and extension) (fig. 7-5), cause the finger tendons to rub on the structures forming the carpal tunnel. This constant rubbing can cause the tendons to swell (tenosynovitis), eventually putting pressure on the median nerve inside the carpal tunnel. The nerve itself is stretched

Figure 7-3.—Major Nerves in the Arm and Hand



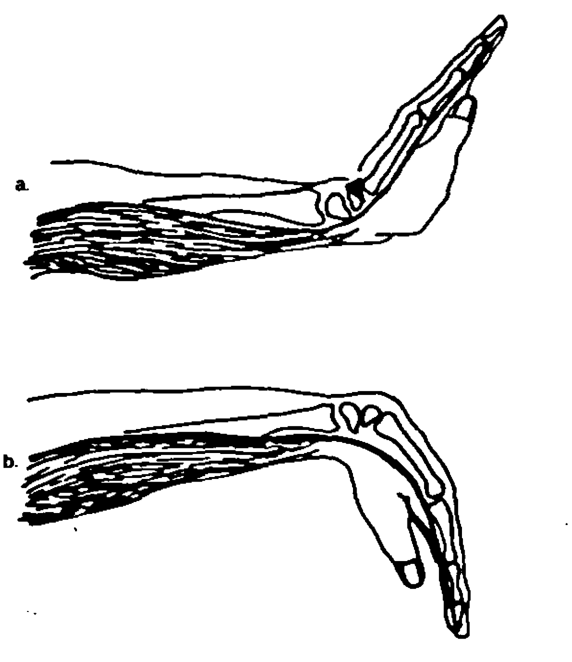
SOURCE: (60)

Figure 7-4.—The Carpal Tunnel



SOURCE: (60)

Figure 7-5.—Flexion and Extension of the Wrist



Bending the wrist causes the finger flexor tendons to rub on adjacent surfaces of the carpal tunnel.

SOURCE: (60).

by repeated exertions, and compressed between the walls of the carpal tunnel.

Forceful movements and the direction of the movement are only two of the underlying causes of tenosynovitis that can lead to CTS. The speed of movements and incorrect posture while working also are important (275). Median nerve compression also can be caused by tasks that require a sustained or repeated stress over the base of the palm (247). Examples include the use of screwdrivers, scrapers, paint brushes, and buffers.

Although the mechanism is not yet understood, low frequency vibration is a recognized risk factor for CTS (405). Vibration exposure may result from air- or motor-powered drills, drivers, saws, sanders, or buffers. Cannon (95) examined medical records at an aircraft company and found a strong association between CTS and use of vibrating tools.

Control of CTS

Control of CTS requires a two-pronged approach. The primary strategy to prevent cases is the use of ergonomic principles to modify handtools and to improve work-station design and work practices. Even a successful ergonomic program will not prevent all cases of CTS, however. The second important element, therefore, is a medical surveillance program. This is particularly important now when so little is known about the individual factors that cause some people to develop CTS. Thus far, no programs focusing on the medical evaluation of CTS seem to exist (60).

Ways are needed to identify the earliest sign of CTS, to evaluate progression of the disease, and to examine the role of predisposing risk factors. The purpose of such a medical surveillance program is prevention of advanced disease by instituting therapy at early stages.

Although medical surveillance for CTS is still in very early stages, ergonomic interventions have been remarkably successful where they have been instituted. Armstrong (21) describes the steps involved in developing appropriate controls. First, plants and specific departments within plants in which there is a documented high rate of CTS should be identified. Then each job should be systematically analyzed. Traditional time-and-motion studies, in which each movement or act is recorded, can be used. Each element of the job can then be checked against factors known to be associated with CTS development. These include posture of the hand and wrist, strength, stress concentrations over the palm, vibration, cold temperature, and the presence of gloves.

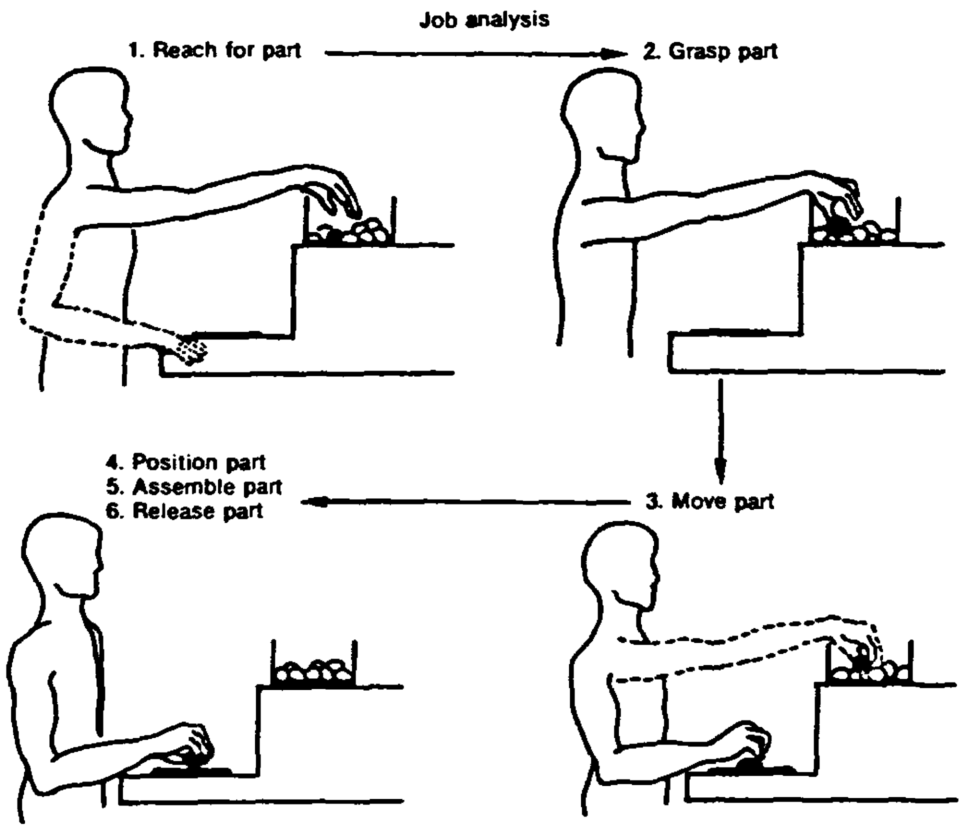
Armstrong presents a typical work task as an example. Figure 7-6 shows a worker taking parts out of a container and placing them on a conveyor. The six elements involved in this task are reach, grasp, move, position, assemble, and release. Reaching into the container involves wrist flexion and pinching, during which the worker's wrist is likely to rub on the edge of the box. The forearm is also likely to rub on the edge of the work bench while the part is positioned. The redesigned work station should reduce stress on the hand and wrist, and eliminate sharp edges. Good and bad designs for the container and the workbench with jig in this hypothetical case are illustrated in figure 7-7.

Powered handtools can also be designed and used to minimize stress. As illustrated in figure 7-8, good designs allow the work to be done with little or no flexion or extension of the wrist.

Armstrong and his colleagues have investigated cumulative trauma disorders in a poultry processing plant using the procedures described above. They discovered that workers in the "thigh boning" section had the highest incidence of cumulative trauma disorders of all departments. Thigh boning involves grabbing the thigh with one hand on a moving overhead conveyor, then making four cuts with the other to separate the meat from the bone. Each worker makes an estimated 15,120 cuts per shift. Ergonomic improvements to the process recommended by Armstrong and colleagues include training workers in the "proper work methods and knife maintenance to minimize the time and, hence, the distance that must be reached and force that must be exerted on the thigh." The work station could be modified to minimize the distance to be reached. The workers wear wire mesh gloves with rubber gloves underneath, which increase the force necessary to grasp the thigh and pull the meat away. Gloves should fit well, and the addition of barbs on the palm of the wire mesh glove might facilitate the hand actions. A new knife handle design, to reduce the force required to hold the knife and make the cuts—e.g., that pictured in figure 7-9—is suggested (22). Such a design would also minimize wrist flexion.

A high incidence of repetitive trauma disorders, including carpal tunnel syndrome, in a telephone assembly plant prompted management to consider how to prevent future cases. McKenzie and colleagues (299) noted the highest rates in areas using vibratory air screwdrivers, and in jobs requiring repetitive grasping, squeezing, or clipping motions. Ergonomic changes recommended included modifying the screwdrivers with sleeve guards and changing work positions to minimize hand and wrist stress. The changes were instituted with almost immediate results: from 2.2 percent annual incidence of repetitive trauma disorders in 1979

Figure 7-6.—Job Analysis: Assembly Tasks



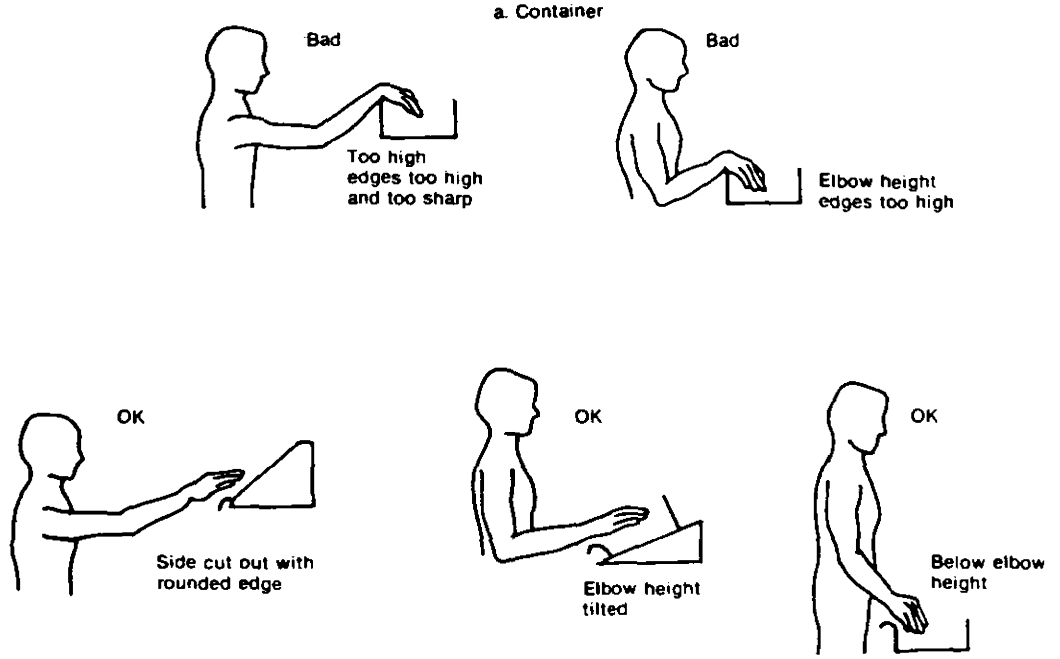
Assembling parts on a moving conveyor can be described by a series of six elements.

SOURCE: (21)

to 0.79 in 1981. Lost and restricted workdays fell from 5,471 in 1979 to 1,111 in 1981, and further reductions were expected in subsequent years.

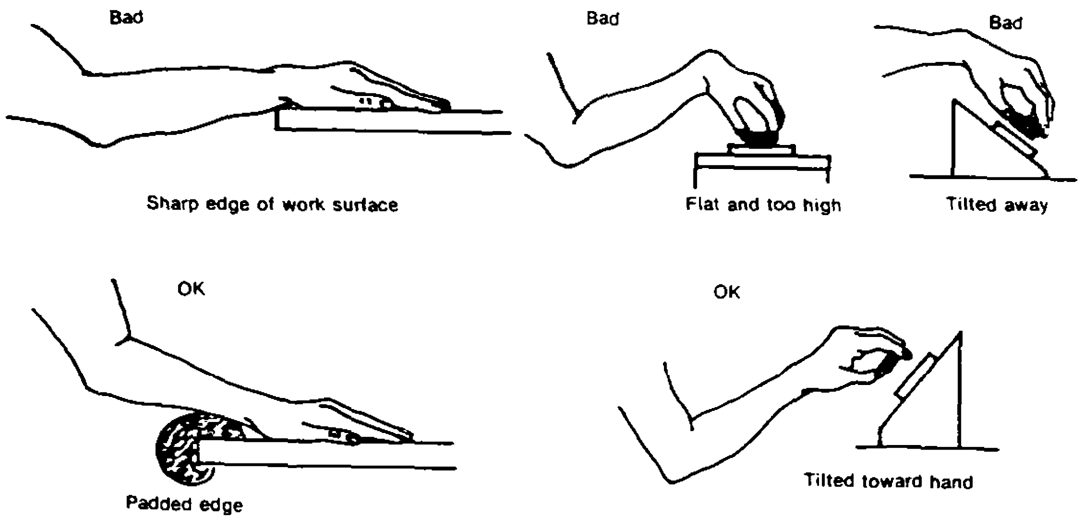
Figure 7-7.—Good and Bad Designs for Containers and Workbenches

a. Container



Containers should be designed so that workers can reach all locations without flexing their wrist. All edges that come into contact with the worker should be well rounded.

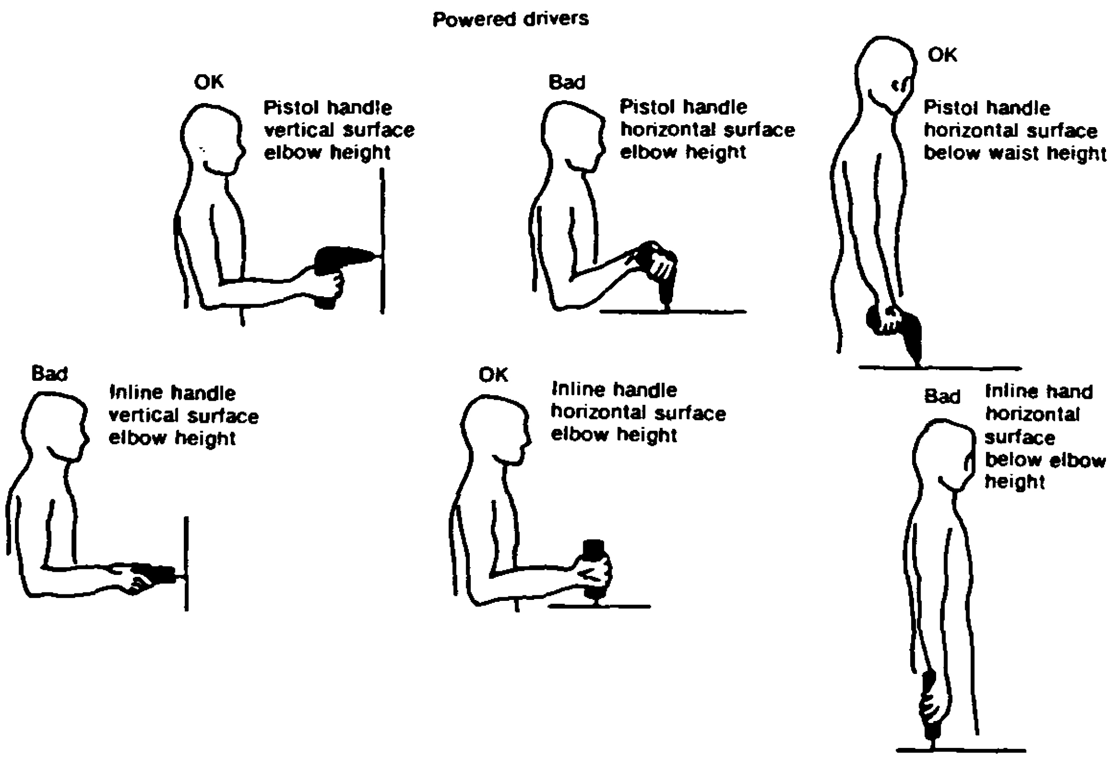
b. Workbench and jigs



Jigs should be located and oriented so that parts can be assembled without flexing the wrist.

SOURCE: (21).

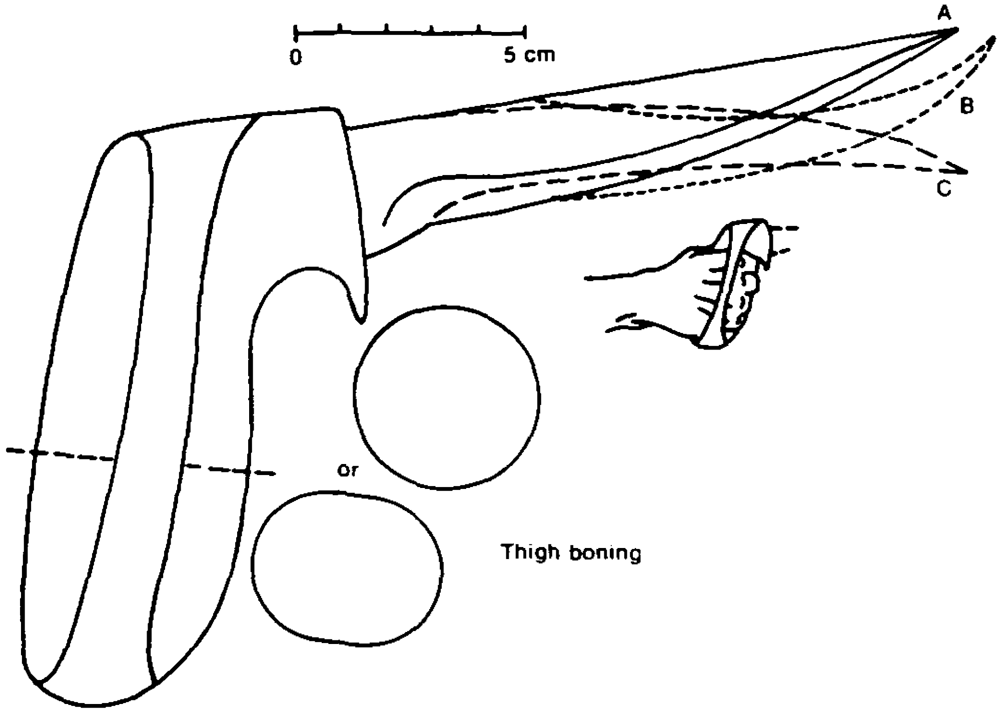
Figure 7-8.—Good and Bad Designs for Powered Drivers



Wrist posture is determined by the elevation and orientation of the work surface with respect to the workers and the shape of the tool.

SOURCE: (21)

Figure 7-9.—A Knife Designed to Reduce Cumulative Trauma Disorders in Poultry Processing



One possible knife handle with three blades for reduced wrist deviations. The handle is designed to reduce the tendency for the knife to fall out of the hand in thigh boning.

SOURCE: (22)

21. Armstrong, T. J., "An Ergonomics Guide to Carpal Tunnel Syndrome," typescript, no date.

22. Armstrong, T. J., Foulke, J. A., Joseph, B. J., et al., "Investigation of Cumulative Trauma Disorders in a Poultry Processing Plant," American Industrial Hygiene Association Journal 43:103-116, 1982.

23. Armstrong, T. J. and Langolf, G. D., "Ergonomics and Occupational Safety and Health," in Enviromental and Occupational Medicine, W. N. Rom, A. D. Renzetti, and J. S. Lett (eds.) (Boston, MA: Little, Brown & Co., 1983).

60. Bleecker, M., Carpal Tunnel Syndrome: A Case Study (Working Paper #15 of Preventing Illness and Injury in the Workplace), contract report prepared for the Office of Technology Assessment, U.S. Congress, Washington, DC, May 1984.

95. Cannon, L. J., Bernacki, E. J., and Walter, S. D., "Personal and Occupational Factors Associated With Carpal Tunnel Syndrome," Journal of Occupational Medicine 23:255-258, 1981.

247. Kendall, D., "Etiology, Diagnosis and Treatment of Paresthesia in the Hand," British Medical Journal 2:1633-1640, 1960.

250. Keyserling, W. M., "Occupational Safety and Ergonomics," in Occupational Health, B. S. Levy and D. H. Wegman (eds.) (Boston, MA: Little, Brown & Co., 1983).

275. Luopajarvi, T., Kuorinka, I., Virolainen, M., et al., "Prevalence of Tenosynovitis and Other Injuries of the Upper Extremities in Repetitive Work," Scandinavian Journal of Work, Enviroment and Health, vol. 5, Supplement 3, 1979.

299. McKenzie, F., Storment, J., Van Hook, P., et al., "A Program for Control of Repetitive Trauma Disorders in a Telephone Factory," typescript, no date.

405. Rothfleisch, S. and Sherman, D., "Carpal Tunnel Syndrome: Biochemical Aspects of Occupational Occurrence and Implications Regarding Surgical Management," Orthop. Rev. 7:107-109, 1978.

567. Citation unknown.

603. U.S. Department of Labor, Bureau of Labor Statistics, Work--related Hand Injuries and Upper Extremity Amputations, Bulletin No. 2160 (Washington, DC: Government Printing Office, 1982).

Carpal Tunnel Syndrome Part I—The Problem

By Edward D. Dionne

When early Stone Age Man began chip-chip-chipping away while using ill-designed tools and poor job techniques to perform a repetitive task, he may have become the first victim of *Carpal Tunnel Syndrome* (CTS.)

Eons later, Carpal Tunnel Syndrome is still with us, and may be increasing for those same three basic reasons: Ill-designed tools, poor job techniques, and repetitive work processes involving the hands.

The carpal tunnel is a canal bordered on the bottom and sides by bone, and covered with a fibrous sheath called the *flexor retinaculum*. This canal leads from the forearm to the hand; the median nerve passes through it—well-protected under normal conditions, but still vulnerable to damage. One result can be CTS.

As explained for the layman by David Hinkamp, M.D., of the Division of Occupational Medicine at Chicago's Cook County Hospital:

CTS is a disorder caused by injury of the median nerve where it passes through the wrist on its way from the forearm to the hand. Injury to this nerve can cause impaired function. This condition is Carpal Tunnel Syndrome, which usually begins with a tingling, or numbness in the hand and fingers, and may progress to a loss of feeling, loss of grip, and, finally, a loss of some hand functions.

Editor's Note: This is Part I of a two-part article on Carpal Tunnel Syndrome. *Part II, "The Solution," will appear in the April issue of NSNews.*

Down through the years, CTS's ramifications have extended into such varied trades and crafts as stone-cutting, weaving, garment-cutting, hand-sewing, meat and poultry processing, electronics assembly work, riveting, word processing, and the piloting of helicopters, to name but a very few affected occupations.

Carpal Tunnel Syndrome disrupts work scheduling, affects production, increases compensation costs.

Indeed, the condition can affect virtually anyone involved with repetitive motions of the wrist area, whether one is performing a simple, direct hands-on work process, such as sorting and flipping mail, or whether one is holding a tool—customarily a pair of pliers, cutters, or screw driver, but keep in mind that for some workers the tool may be a control button, a pencil, a telephone, or an assembly part.

More than a century ago—in 1865—the first description of Carpal Tunnel Syndrome appeared in medical literature when Sir James Paget, in his surgical pathology lectures, described a condition where compression of the median nerve occurred following fracture of the wrist.[1]

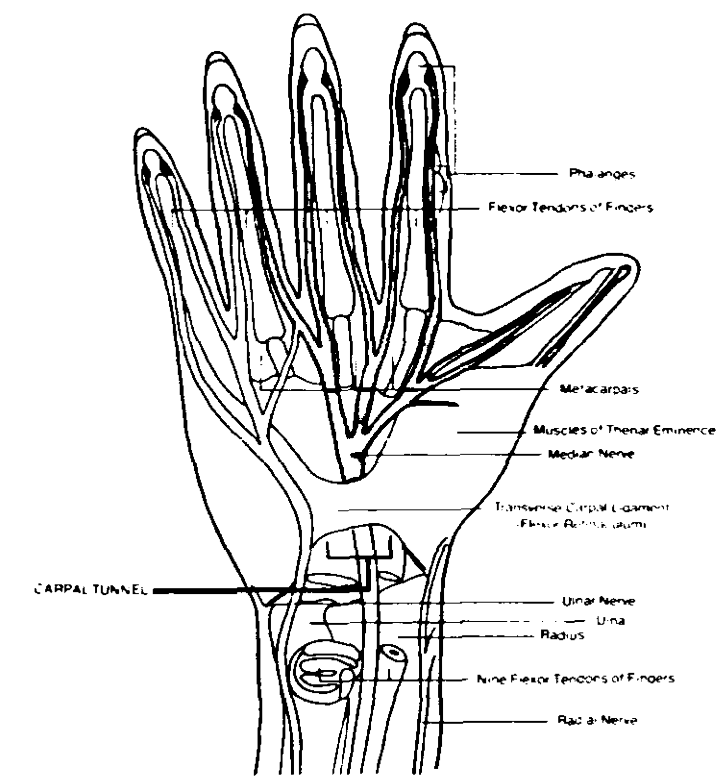
Although early known to the medical profession, CTS only comparatively recently has attracted the attention of NIOSH, the insurance business, ergonomics engineers, tool manufacturers, and even the work glove industry. All are especially interested in CTS because its effects on employees can disrupt work schedules, affect production, and increase Workers' Compensation costs, in addition to causing personal suffering and disability.

Dr. Hinkamp further explains:

A person may first notice CTS as a tingling, numb, pins-and-needles sensation, usually occurring some hours after work or during sleep. This happens to everyone, occasionally, but it persists in the individual with CTS. The affected person may awaken regularly and have to shake his or her hand to help regain normal feeling. Then, as the syndrome progresses, this sensation becomes more frequent, eventually occurring in the daytime, too. Eventually, clumsiness and weakness also become evident.

A lot of people who have CTS attribute the numbness and tingling to arthritis or aging. And some people think that when they go to work, their hands will hurt, and that's just the way it is.[2]

But, while numbness, tingling, and loss of function in the hands also can be caused by arthritis, diabetes, or other ailments, researchers also are finding many times that a person's work or hobby may involve repetitive activities that eventually can cause CTS, Dr. Hinkamp points out. Before coming to Cook County Hospital, he worked at the Universi-



Graphic illustrates palm view of the right hand, showing relationship of carpal tunnel, nerves, ligaments, tendons, muscles, and bones.

ty of Michigan with others early involved in such research.

One of those researchers is Thomas J. Armstrong, Ph.D., Associate Professor, Department of Environment and Industrial Health at the University of Michigan at Ann Arbor. A paper he recently authored,[3] when studied in conjunction with the accompanying illustrations, helps the industrial hygienist and safety specialist to understand further CTS.

Armstrong explains that CTS "is a disorder of the hand caused by injury to the median nerve inside the wrist. The median nerve is one of three major nerves of the upper extremity that contains motor, sensory, and autonomic fibers. Injury of the median nerve results in impaired or lost nervous function in the first three and one-half digits and the thenar eminance at the base of the thumb. Motor nerve impairment results in reduced muscle control and ultimately muscle atrophy; thenar atrophy is a common symptom in advanced cases of carpal tunnel syndrome."

Again speaking to the layman, Dr. Hinkamp states:

"There are a lot of things we don't know about this syndrome, such as how many repeated twists of the wrist may cause how much damage to each individual. We know that a majority of the people suffering from these work-related injuries are women. In one Michigan study, for instance, just 49 per cent of those in the study were female, but 73 per cent with the disease were women.

"We don't precisely know if there is something about women that makes them more likely to get the disease, or if women just tend to be assigned to jobs that tend to cause it."

Some sources state that CTS "occurs most often in patients between the ages of 30 and 60 years of age, and is three to five times more frequent in women than in men."[1]

A *Health Hazard Evaluation Report*[4] issued by NIOSH presents information currently of interest to those studying CTS. The report states that CTS occurs from three to 10 times more often in women than in men, and it may be associated with a host of other diseases and conditions. Some of these predisposing conditions—including wrist fracture, arthritis, cysts, and acromegaly—can be explained on a purely mechanical basis, "because the tunnel becomes smaller or the contents become larger and compression of the tunnel contents occurs."

The NIOSH report adds that other related disease states or conditions, including diabetes, hypothyroidism, dialysis, pregnancy, oral contraceptive use, menopause, and perhaps Vitamin B6 deficiency, appear to predispose individuals to the development of CTS through complex nutritional, vascular, biochemical, and anatomical factors.

Carpal tunnel syndrome is frequently seen in pregnancy due to retained fluid (edema); it is usually self-limiting, with the symptoms disappearing after birth. And because patients with CTS are women at or near menopause, hormonal changes may be playing some causative role, it is believed by some investigators.

CTS also has been linked prominently to ergonomic factors, NIOSH states. There have been several important biomechanical experiments that demonstrated pressure increases within the carpal tunnel when both the wrist and the fingers are flexed. In several cases it was noted that occupations involving considerable use of the hands appeared to predispose individuals to CTS.

Examples within one study included persons who performed milking, ladling, and spray painting, with the index finger and middle fingers compressing a trigger, NIOSH states.

In a medical record review of 250 consecutive cases of CTS, the NIOSH report points out, it was demonstrated that the dominant hand is affected more often and more severely, suggesting that more frequent and more intense hand use plays a role in the development of CTS.

In two workplace case control studies cited in the NIOSH report, ergonomic factors were among identified risk factors. These included frequent deviation from neutral wrist position, frequent use of the 'pinch' grasping hand position, and repetitive wrist and hand movements. Gynecologic surgery with oophorectomy (surgical removal of one or both ovaries) was also a risk factor. Despite limitations in these studies, they provide suggestive and supportive evidence for ergonomic (as well as hormonal) risk factors.

Armstrong suggests that because there is not sufficient evidence to use endocrinological factors for selecting or placing workers, employers should concentrate on controlling work factors.

The NIOSH report continues:

"Although CTS is by no means a purely and specifically 'occupational' disease, there is little question that hand and tool usage, alone or in combination with other factors, may lead to the development of a compression neuropathy of the median nerve."

Although the precise mechanism whereby hand use results in CTS is not known, proposed mechanisms include:

1) Repetitive increases in the intra-tunnel pressure, with consequent trauma to the nerve directly;

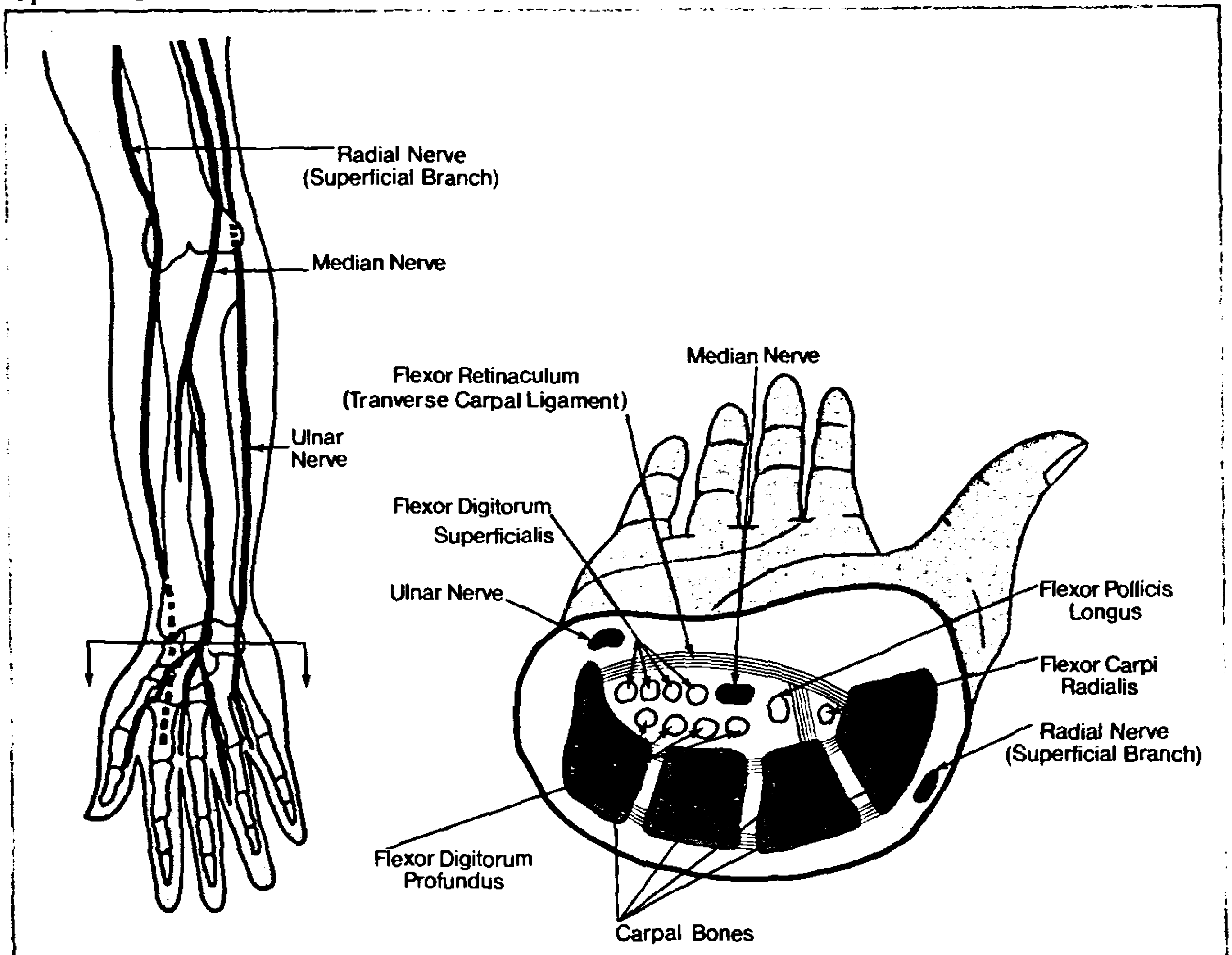
2) Activity levels that exceed the lubricating capacity of the flexor sheath, resulting in friction, mild inflammation of the flexor sheath, and swelling, with secondary compression of the nerve;

3) Some combination of the two.

Armstrong reports[3] the overall incidence rate and prevalence of Carpal Tunnel Syndrome in the work force is not yet known. Although the available data vary considerably from site to site and job to job, they show that Carpal Tunnel Syndrome and related illnesses are a major problem in some settings.

Armstrong then cites these frequently reported non-occupational factors of Carpal Tunnel Syndrome:

- *Systemic diseases*—Such as rheumatoid arthritis, acromegaly, gout, diabetes, myxoedema, ganglion formation, and certain forms of cancer.
- *Congenital defects*—Including bony protrusions into the carpal tunnel, anomalous muscles extending into or originating in the carpal tunnel, and the shape of the median nerve.
- *Wrist size*—Although recent stud-



Graphic illustrates nerves of the right arm descending to the wrist and hand; the view is of the palm side of the hand. The adjacent graphic presents a sectional view of the right wrist at the carpal tunnel area.

ies of CTS patients made with the use of computerized axial tomography (CAT scanner) suggest that there is an association between a very small carpal tunnel and idiopathic carpal tunnel syndrome, Armstrong and Chaffin, in a study[5] of personal factors, were unable to find any association between hand and wrist size and occupational carpal tunnel syndrome.

• *Acute trauma*—Median nerve injury inside the carpal tunnel can be produced by a blow to the wrist, laceration, burn, or other acute wrist trauma.

• *Pregnancy, oral contraceptives, menopause, and gynecological surgery*—All have been reported as factors of carpal tunnel syndrome. Because all are uniquely female problems, they may, in some cases, contribute to a disproportionately high incidence rate of the syndrome in females.

Armstrong's *An Ergonomics Guide to Carpal Tunnel Syndrome* continues with this advice:

"Non-occupational factors may suggest the need for medical screening, but so far there are no reliable pre-employment indicators of worker predisposition to Carpal Tunnel Syndrome. As a practical matter, employers probably will find it easier to exercise control over the design of jobs than over the selection of workers."

Although to date there has been no major industry-wide, all-employee study of the presence or the extent of CTS, a search of the literature reveals many limited and controlled studies conducted or sponsored by individual companies, medical schools, universities, NIOSH, and insurance companies. The interested NSNEWS reader would do well to study the "Bibliography" accompanying this two-part article for specific, detailed information.

As Armstrong and Hinkamp recommend, evaluation of CTS and related cumulative trauma illnesses includes analysis of health data to identify jobs in which there is an elevated incidence of Carpal Tunnel Syndrome, together with an analysis of work methods to identify the risk factors previously described.

Sources of health data suggested by Armstrong and Hinkamp include:

- First aid logs;
- Medical visit logs;
- Medical reports;
- Workers' Compensation reports;
- OSHA logs;
- Personnel benefit records.

It is recommended that these records be reviewed for CTS and all other related illnesses, such as tenosynovitis and strains, because experience has shown that these other illnesses sometimes are associated with CTS, and they often are a result of the same kinds of stresses as is Carpal Tunnel Syndrome.

Incidence rates should be computed for each job classification or department to identify those areas where the risk of developing repetitive trauma disorders is considered "unacceptable."

The incidence rates for CTS in job groups without hand-intensive work, such as supervisors and managers, can be used as a reasonable goal for hand-intensive jobs. Once the problem areas have been identified, the jobs should be systematically analyzed for occupational factors of CTS, Armstrong advises, and such factors eliminated or minimized where possible. Traditional time-and-motion study procedures, in which a job is divided into a sequence of acts or elements for the right and left hand, can be used to describe what the worker does.

Bernard[1] cites two modes of treatment for CTS, *i.e.*, conservative and surgical. If mild symptoms have been present for less than two months, conservative treatment may be given with resulting relief, Bernard states.

Conservative treatment might include resting the hands, or changing the occupation of the patient who has had a recent onset of symptoms after doing manual labor. Other conservative methods include: proper control of diseases associated with CTS, wrist splinting, anti-inflammation medicine, and injection of hydrocortisone into the carpal tunnel.

Conservative therapy can be slow, but it is very important, Dr. Hinkamp points out.

When signs and symptoms are persistent and progressive, and CTS is advanced or rapidly progressing, then surgery may be necessary. The surgical treatment involves the division of the entire transverse carpal ligament (flexor retinaculum).

Post surgical recurrences of CTS can occur, but this is not frequent. The causes of the recurrence can be due to incomplete division of the transverse carpal ligament, post-surgical fibrous proliferation, or recurring tenosynovitis.

Now that the problem of Carpal Tunnel Syndrome has been well-identified by the medical world, NIOSH, and others, answers are slowly forthcoming. Currently contributing their expertise in solving the problem are labor unions, the insurance industry, ergonomics engineers, tool makers, and the work glove manufacturers.

It appears that the problem of Carpal Tunnel Syndrome currently is in good hands. Ω

References

1. *Bernard, Marsha Lynn, R.N., M.S.N.,* "Carpal Tunnel Syndrome: Identification and Control," *June 1979.* ***Occupational Health Nursing.*** *Charles B. Slack, Inc., Thorofare, N.J., 08086. pp. 15-17.*

2. *Van, Jon, "A Repetitive Job More Than Boring: It Can Hurt Hands."* ***The Chicago Tribune,*** *435 N. Michigan Ave., Chicago 60611. Jan. 16, 1983.*

3. *Armstrong, Thomas J.,* ***An Ergonomics Guide to Carpal Tunnel Syndrome,*** *Ergonomics Guide Series, American Industrial Hygiene Association, 475 Wolf Ledges Parkway, Akron, OH 44311. 1983.*

4. ***Health Hazard Evaluation Report No. 81-409,*** *(includes section on Carpal Tunnel Syndrome). NIOSH, Technical Information Branch, Division of Standards Development and Technical Transfer, Robert A. Taft Laboratories, 4676 Columbia Parkway, Cincinnati 45226.*

5. *Armstrong, T. J., and D. B. Chaffin, "Carpal Tunnel Syndrome and Selected Personal Attributes,"* ***Journal of Occupational Medicine,*** *Flournoy Publishers, Inc., 1845 W. Morse Ave., Chicago, 60626. July 1979. Vol. 21, No. 7, pp. 481-486.*

EDITOR'S NOTE: *Part II, dealing with possible answers to The Problem of Carpal Tunnel Syndrome, will include Acknowledgments and a comprehensive Bibliography.*

Carpal Tunnel Syndrome— Part II: Some Answers

By Edward D. Dionne

Two modes of treatment—termed conservative and surgical—have been proposed in dealing with the problems of CTS.*

The conservative method applies human factor engineering principles to analyze repetitive motion jobs to identify those considered stressful, and applies these same principles to reduce such stress. The simplest solution is to provide employee rotation within the working group to minimize stressful exposure. For instance, in an assembly line process, the total job may encompass 20 sub-tasks. When the sub-tasks are analyzed, the analysis may show that two or three are stressful. It may be possible to rotate line employees between these sub-tasks on two-hour intervals.

This was the approach taken by Harvey E. Foushee, Corporate Human Factors Engineer, AT&T Technologies, Inc., of New York, at a "Blockbuster" session of the 71st National Safety Congress, held last October at Chicago.

As stated by Foushee:

"Industrial companies are finding the application of human factors engineering principles useful in reducing pain and soreness complaints, which contribute to CTS cases in the workplace. When hand force is exerted on tool handles, there will be some compression transmitted to the tendons and their respective tendon sheaths, as well as the nerve bodies. The tool handle length and diameter will be an important consideration to minimize this compressive force. When the compressive force is combined with repetitive motion that requires hand deviation from the straight-line axis, the combination of compression and deviated hand and arm posture may cause inflammation of the nerves, resulting in the loss of sensory feedback mechanisms." (See Figures 1 and 2.)

Foushee recommends:

- Provide and orient jigs or fixtures to permit assembly activity to occur within the normal range of arm movement (See Figure 3);
- Provide cushioned arm rests to support the forearm, thus increasing the manipulative ability in the hand (See Figure 3);
- Store parts in containers designed for employee reaches with minimal hand flexion or extension;
- Provide for downward force movements through flanged surfaces on tool handles (See Figure 4);
- Provide for vibration dampening of tools through the use of rubber-backed low-pile carpet on work surfaces;
- Provide radiused (rounded or curved) edges on fixtures to minimize point-source pressure on the

*EDITOR'S NOTE: See "Carpal Tunnel Syndrome: Part I—The Problem," in the March issue of NSNEWS.

Figure 1, an X-ray of the hand holding an ergonomically designed pair of needle-nose pliers, shows the proper axis of thrust for handling such tools. A spring located between the handles facilitates their opening. A flange has been added to the top of the upper handle as a point for the thumb to push against.

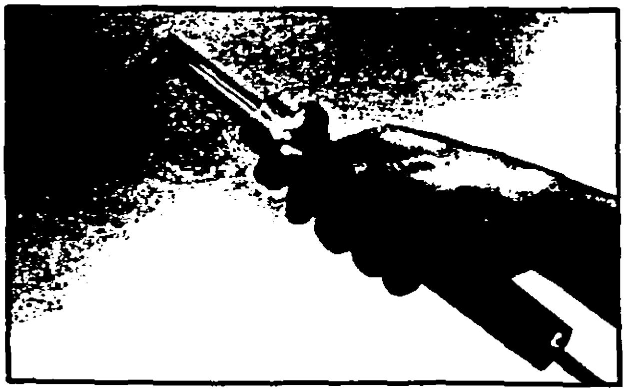


Figure 2 shows a soldering iron with the head at right angles to the handle, which has been designed to extend beyond the soft spot of the palm, placing the work force against the muscle of the little finger. The flange also offers the worker security against solder splash.

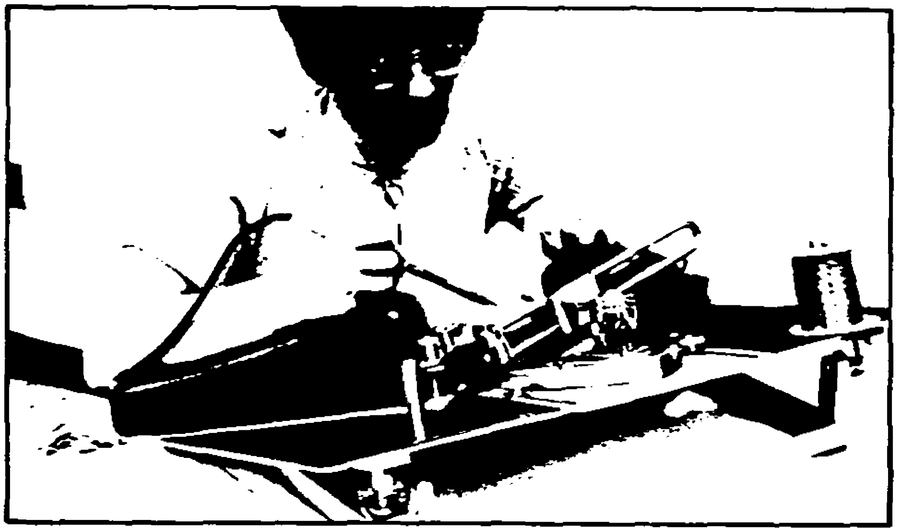


Figure 3 shows a worker doing an exacting soldering task, using a padded fixture instead of resting her arms on the edge of the work table, which cuts into the forearms with resultant problems.

arms (See Figure 5);

- Provide training of employees in correct tool use;
- Select hand tools that spread the stress areas evenly over muscle eminences (See Figure 6);
- Maintain power tools at proper torque requirements;
- Consider power tools that stop when the torque setting is reached—(When this principle is ignored, the G forces transmitted into the hand tissue will increase dramatically);
- Suspend power tools on balancers to support the tool weight; this will minimize the static load on the muscle bodies for lengthy time periods (See Figure 4);
- Select tools that consider hand size variables in workers;
- Select tool handle surfaces to provide control and a relaxed grip force;
- Avoid fluted surfaces that concentrate stress over small point-sources in the hands.

The conservative approach to CTS also was discussed at a Congress session sponsored by the Council's Labor Division. Speakers were Roger Stephens, Ph.D., an ergonomist at the Washington, DC office of OSHA, and Ed Golonka, Industrial Hygienist, AT&T Technologies, Inc., Hawthorne Station, Chicago.

Stephens presented a comprehensive view of CTS—what it is, its effect upon various industries, and directions the U.S. Department of Labor is taking in the way of research and other methods of remedying CTS and other industrial traumatic conditions, including those resulting from repeated and excessive body movements and machine vibrations.*

Golonka explained how ergonomically and biomechanically designed and engineered hand tools, work area furniture, and procedures helped combat CTS and other diseases at the Hawthorne plant, where the assembly of electronic and telecommunications equipment is conducted.

Golonka stressed that detailed observations of work procedures revealed some basic—but important—principles related to assembly workers:

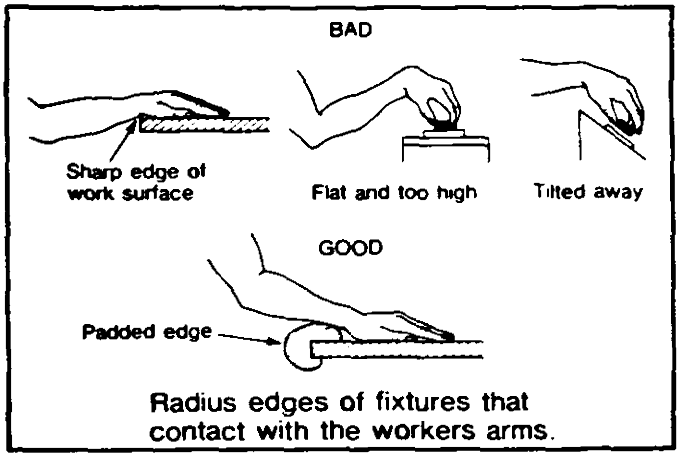
- People can be ambidextrous.
- Much can be learned by paying close attention to skilled, experienced workers as to how they do their jobs; watch them closely for solutions, in addition to those with the problem.
- Experienced workers are resourceful; some were found to orient their bodies relative to the work fixture, and this orientation differed by almost 120 to 140 degrees between right-handed and left-handed employees. One ingenious solution devised by the company's engineering staff is a unique "Vice-Versa Machine," capable of being adapted easily to hold and support the work to fit the employee's own individual hand needs, whether that worker be right-handed or left-handed.

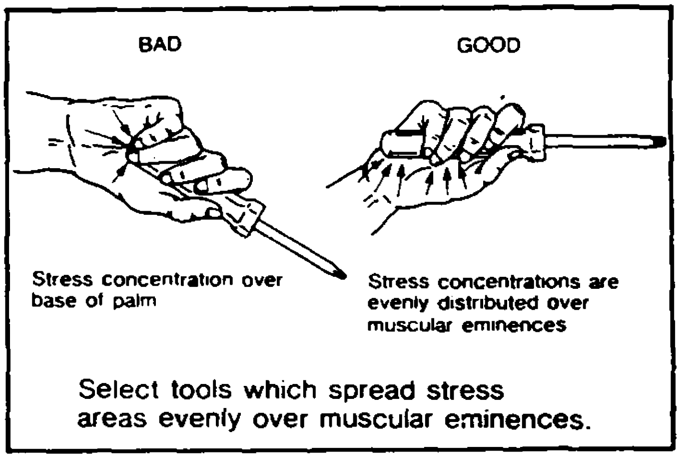
Even a familiar, everyday procedure such as pushing a control button can, in time, set up a traumatic condition, explains David B. Knight, M.P.H., Executive Director of Product Development for CIGNA's Loss Control Services, Inc., at Philadelphia. He says:

"One of the most common elements of work is activation of machinery or equipment by hitting control buttons. It is not uncommon for an operator to activate equipment every four or five seconds. Allowing for rest intervals and other tasks, this may mean the hands must perform the motion pattern more than 5,000 times per day. It becomes imperative, therefore, that consideration be given to both the hand position and the force required to engage the control. Different controls may vary considerably in the amount of force re-

*See also "Positioning Health and Safety in the '80's" February NSNEWS, pp. 40-44.

Figure 4 shows a flange of padded material on a powered screw driver. The flange acts as a structure the employee can push against, giving a feeling of security and eliminating need to grip the tool tightly. Note the suspension system to lessen tool weight.





Figures 5 and 6 illustrate good and bad work practices and tool handling as related to Carpal Tunnel Syndrome.

quired, and this should be given due attention in the selection of different devices. Touch-sensitive controls now available virtually eliminate forces."

Knight also points out that where switches are placed —and their shape—can have a significant effect on the position of the hand and the consequent deviation of the wrist. Other design-related principles presented by Knight include those pertaining to collars added to some tools and machines in an effort to protect the control switch from accidental activation, or from deliberate attempts to defeat two-hand controls. Such devices, designed for safety purposes, may increase stress on tendons, Knight states, and attention should be given to alternative guarding methods when workers are experiencing cumulative trauma disorders.

Additional guidelines for the conservative approach to CTS are offered by Thomas J. Armstrong, Ph.D., Associate Professor at the University of Michigan's Center for Ergonomics, at Ann Arbor:*

- The frequency of work sometimes can be reduced by eliminating wasted motions and minimizing reach distances; however, in many cases it cannot be reduced without reducing the rate of work.
- The force of work often can be reduced by reducing the size of containers or bundles. Force also can be minimized by using only parts that fit properly, and machines that are adjusted properly. Quality control and maintenance people should be consulted for help in this area.
- The effective force can be reduced by gripping objects, rather than pinching them; the body has to work four to five times harder to pinch than to grip.
- The force of work can be reduced by avoiding poorly fitting gloves. Gloves easily can reduce strength by 30 per cent. A variety of glove sizes and styles should be made available so that workers can find the ones that are most comfortable for their particular job.
- The amount of force exerted is related to the feel of the force in the hand. The sense of feel can be reduced and even eliminated by exposure to low temperatures. Hand temperatures should be maintained at temperatures that do not feel cold to the touch of protected areas of the body.
- The position of the wrist is determined by the shape of the object held or manipulated with the hand, and the location and orientation of the work surface. For example, wrist deviation is required to hold and use an in-line nut-runner on a vertical surface at elbow-height. The posture can be controlled by changing the location or orientation of the work surface, or by changing the tool itself. A pistol-shaped nut-runner could be held against a vertical surface at elbow height without excessive postural stress. In another example, wrist flexion is required to hold a pistol-shaped nut-runner on a horizontal bench surface. Again, the posture could be controlled by reorienting or relocating the work surface or by changing tools. In this case, an in-line shaped handle would minimize postural stress.
- Stresses often are produced on the base of the wrist by pressing with the palm or by holding a tool. Forceful exertions with the base of the palm should be avoided. Where this is not possible, protective pads

Figure 7 shows James McClatchey of AT&T Technologies, Inc., holding contoured needle-nose pliers with hand grips designed to minimize repetitive motion disease. On the table are other specially adapted tools, including two models of an air-powered triggerless wire wrap gun, an air-powered screwdriver with cushioned plastic sleeve, and a hatchet-shaped soldering gun.

*See also "Carpal Tunnel Syndrome—Part I: The Problem," and "Are Your Work Procedures a Menace?" in the March issue of NSNews.

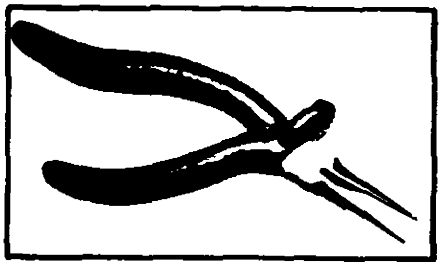


Figure 8 shows a pair of long-nose pliers, specially designed, padded, and with thumb flange to minimize problems of CTS. (Photo: Courtesy Klein Tools, Inc.)

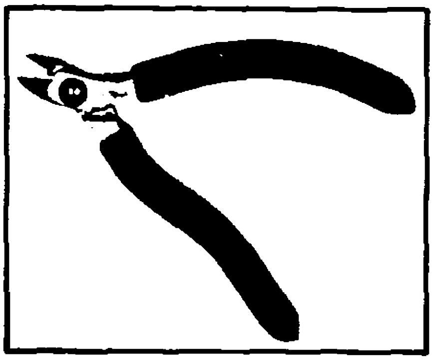


Figure 9 shows an ergonomically designed cutter, with soft foam cushion grips and internal spring. (Photo: Courtesy Erem Corp.)

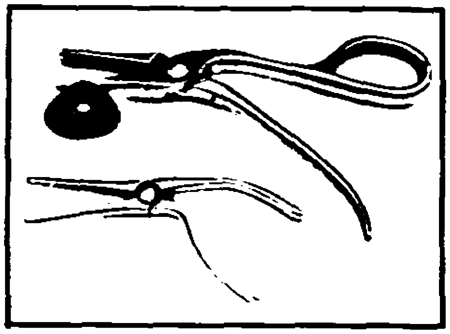


Figure 10 shows two types of ergonomically designed press feeding tools, including one with a vacuum cup attachment. (Photo: Courtesy Osborn Manufacturing Corp.)

should be used. Handles of tools should be long enough to traverse the muscular eminences at the sides of the palm.

• Vibration exposure can come from the use of power tools, impact tools, grinding and buffing, or holding the steering wheel of vehicles. Equipment suppliers and maintenance persons should be consulted for help in selecting and maintaining equipment for minimum vibration.

Carpal Tunnel Syndrome has become a world-wide industrial problem. Helping to solve that problem is James W. McClatchey, department chief, corporate industrial hygiene and human factors engineering at AT&T Technologies, Inc.'s New York office. (See Figure 7.) In 1982 and 1983 he was a member of a technical exchange team visiting the People's Republic of China, a nation seeking improved worker safety as it gears up for industrialization.

McClatchey offered the Chinese his expertise with Western Electric (now AT&T Technologies, Inc.) a company well-known for its long experience in human factors engineering. McClatchey states:

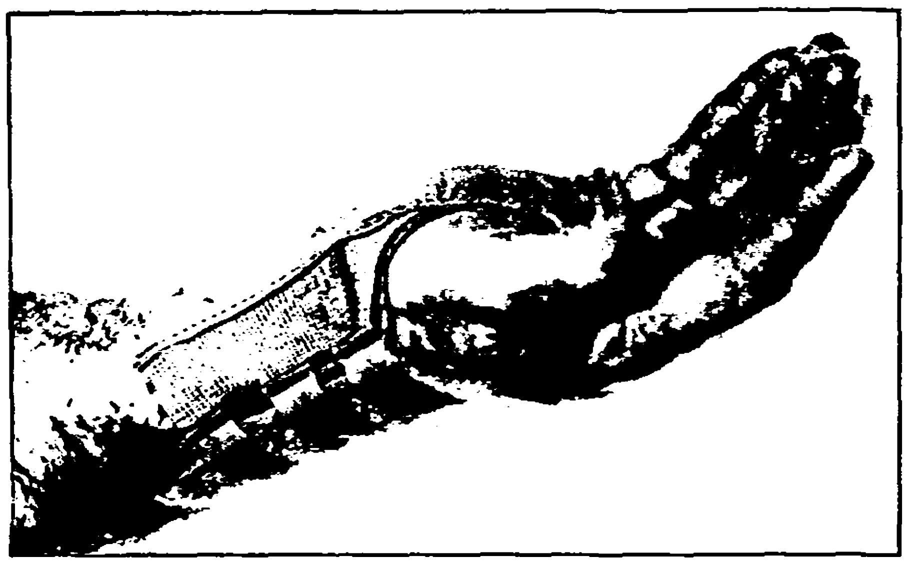
"China's workers are involved in a high degree of repetitive tasks that require significant hand and arm movements. If their tools are awkward to use, the result often is a repetitive motion disease. The solution sometimes can be a simple change in the curvature or shape of a hand tool or a change or redesign of a work station."

Some U.S. tool manufacturers have worked closely with various segments of industry in designing and engineering hand tools to reduce or eliminate carpal tunnel syndrome, tendonitis, and other diseases related to repetitive motions, vibration, and other conditions found in the workplace. (See Figures 8, 9, and 10.)

At East Peoria, IL, an innovative—and somewhat controversial—approach to the problem of hand and wrist diseases has been undertaken by John F. Bennett, Chairman of Bennett Ergonomic Labs. His proposed solution makes use of what he refers to as "the Bennett Bend," or "The Bionic Curve," which incorporates a 19-degree bend in an otherwise customarily straight handle for hammers and other tools, including a line of knives used by workers in the poultry and meat processing industries.* Bennett has extended his theory to the familiar household broom, tennis racquets, and baseball bats.

Still another approach to the problem of CTS is being offered by some manufacturers of work gloves. Although both the Work Glove Manufacturers Association (WGMA) and National Industrial Glove Distributors Association (NIGDA) report there is currently no organized, industry-wide program under way, some individual companies are carrying on their own research and development programs related to repetitive trauma, vibration, and other job-related diseases of the shoulder, arm, wrist, and hand. One glove manufacturer currently has four prototypes for such apparel, designed to "minimize" the problem. He states that his company "has the technical abilities to fabricate, but needs more feedback and suggestions from employers. Such input could refine our efforts toward eliminating the CTS

*See *"Are Your Work Procedures a Menace?"* in the March issue of NSNEWS.



One medical approach to the treatment of Carpal Tunnel Syndrome is a brace with a steel insert to prevent bending of the wrist.

Photo taken only a few days after surgery was performed illustrates the path of incision selected for this case of Carpal Tunnel Syndrome.

problem." Another work glove manufacturer has available a "carpal tunnel" glove, and several companies are marketing mittens and gloves with special padding to combat vibration.

The surgical treatment and medical aspects of Carpal Tunnel Syndrome were discussed at the Congress "Blockbuster" session by Sidney J. Blair, M.D., Chief, Section of Hand Surgery, Department of Orthopaedics and Rehabilitation, Loyola University Medical Center, Maywood, IL.

Surgery for Carpal Tunnel Release is indicated upon failure of conservative treatment, when pain is severe, and there is deterioration of the muscles of the thumb. Electrical tests are used to give the estimate of damage to the median nerve, Dr. Blair explains.

The surgery consists of incising the transverse carpal ligament of the wrist. Splints are worn for a short period to allow healing. Patients' return to work depends on their occupation. Patients who are doing repetitive tasks should be restricted from working for two months, in some cases, Dr. Blair advises.

Some patients will continue to have numbness for several months. Occasionally, patients may develop stiffness and pain following the surgery. This is called "Sympathetic Dystrophy." It will require prolonged therapy, and it will increase the disability. If the ligament is incompletely cut, the symptoms will persist. Most of the patients, however, will obtain relief from their surgery according to Dr. Blair. Ω

Bibliography

Available from National Safety Council, 444 N. Michigan Ave., Chicago 60611:

—***Accident Prevention Manual for Industrial Operations—Administration and Programs,*** *Eighth Edition, 1981. Edited by McElroy, Frank L., PE, CSP, Stock No. 121.41.*

—***Fundamentals of Industrial Hygiene,*** *Julian B. Olishifski, editor-in-chief, Second Edition, 1981. Stock No. 151.27.*

—***Ergonomics Guidebook.*** *1983. Stock No. 15733.0000.*

—***Ergonomics Checklist.*** *1983. Stock No. 15735.000.*

—***Ergonomics At Work***—*Videotape. 1983. Full color, ¾-inch, 14 minutes. Stock No. 0093-15731-0000.*

Strains & Sprains: A Worker's Guide to Job Design, *International Union, UAW, Health and Safety Department, 8000 E. Jefferson, Detroit 48214.*

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Klein Tools, Inc., 7200 McCormick Rd., Chicago 60645.

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Therapy Can Relieve CTS Symptoms

Insight into the mechanical/medical problem of Carpal Tunnel Syndrome is offered by Robert F. Perry, R.P.T., President of Physical Rehabilitation Associates, Champaign, IL. He explains that the strength of the hand's transverse carpal ligament is a major factor in giving the 10 tendons that pass through the wrist area to the hand the mechanical advantage they need for the hand to develop the 120 to 180 pounds that is considered to be normal grip strength. But, he adds,

"It is also the strength and rigidity of this ligament that contributes significantly to the median nerve entrapment problem that we have come to know as Carpal Tunnel Syndrome."

As a physical therapist, Perry believes that the problem may be resolved at its earliest stages—a feeling of tired hands and/or sore wrists—by allowing the irritated wrist to rest until the irritation subsides. A mild anti-inflammatory medication—such as aspirin—often is prescribed by the physician, Perry reports.

But repeated, prolonged, or continuous stresses of this type often can result in a more serious irritation or inflammation of the synovial membranes (a condition called *tenosynovitis*), which will cause them to overproduce synovial fluid and swell. Involvement of the transverse carpal ligament can result in CTS, he states. A common test for CTS, according to Perry, is a measurement of the nerve conduction velocity (NCV) of the median nerve. This test is usually done in both arms, he states, so that the physician or therapist performing the test will have a normal value that can be used as a comparison value. A prolonged conduction time across the wrist joint is considered to indicate the presence of median nerve compression in the carpal tunnel, according to Perry. He also cites the possible use of fairly recent development in medical instrumentation, a non-invasive procedure known as Thermography.*

Perry has observed that the medical treatment of CTS may fall into these categories:

- In the initial stages, a night splint that holds the wrist in slight hyperextension may be prescribed to rest the wrist. Mild anti-inflammatory oral medication also may be prescribed by the physician.

- In the more developed case, it may be necessary for the physician to inject the compartment with a combination of local anesthetic and an anti-inflammatory agent. A splint often is prescribed, to be worn during the day as well as at night to prevent the forceful contraction of the fingers and thumb flexors. In the past, ultra-sound has been used in an attempt to treat the condition. The use of therapeutic ultra-sound at this stage of the condition in some instances may exacerbate the problem by increasing the swelling.

- In patients who either cannot be injected, do not wish to be injected, or have not had a good response to the injection, a trial of physical therapy including controlled laser systems, interference currents, or bioconductive therapy may be indicated.

- In the final analysis, it may be necessary to divide the transverse carpal ligament surgically to obtain a good result. Following surgery, it is important that the patient undergo an adequate program of physical therapy designed to restore strength and flexibility to the wrist and resolve any remaining pain problems. This is especially important when it is anticipated that the employee will be returning to a job where a good grip is a factor in successfully performing the job. An adequate program of physical therapy also can restore the worker's confidence in his ability to perform the tasks implicit in his job, without undue fear of reinjuring himself. The therapist may use further non-invasive instrumentation to document the point at which the neurological changes have been resolved. The physical therapist may use a combination of physical modalities, such as electric stimulation, paraffin baths, or controlled laser systems to reduce any pain that may remain, plus exercises to restore the range of motion to the wrist. The therapist also may fabricate a splint to protect the wrist in the initial stages, following the surgery, if this is indicated by the surgeon. Ω

* *See Meyers, Jonas, and John Fournier, M.D., "Thermography: A Medical Surveillance Tool?" National Safety News, Vol. 127, No. 5, May 1983, p. 37.*

Teleconference on Cumulative Trauma Set for May 16

Experts in the field of carpal tunnel and other cumulative trauma disorders will appear at a National Safety Council sponsored teleconference. It will be beamed by satellite to 53 cities. See page 30 for details.

PART II

CUMULATIVE TRAUMA DISORDERS IN THE WORKPLACE

BIBLIOGRAPHY

A. NIOSH PUBLICATIONS/REPORTS

1. NUMBERED PUBLICATIONS *are formal publications issued by NIOSH that document the results of research conducted by or for NIOSH. Included in this category are Criteria Documents, Current Intelligence Bulletins, Alerts, Health and Safety Guides, technical reports of scientific investigations, compilations of data, worker-related booklets, symposium and conference proceedings, and administrative and management reports. Publications are listed in reverse chronological order.*

1. A National Strategy for Occupational Musculoskeletal Injuries: Implementation Issues and Research Needs. ***1992.***
NIOSH PUB NO: 93-101. 22 pp.
NTIS NO: PB91-173351 PRICE: Check NTIS

The proceedings of a conference on the development of a national strategy for occupational musculoskeletal injuries were summarized. Specific topics discussed included the scope of the national program, major federal government initiatives, the passage of the Occupational Safety and Health Act, definition of acute and chronic musculoskeletal injuries, anatomical structures of concern, multi-factored risk model development, methods used for identifying job hazards, nonoccupational factors and the risk of an occupational musculoskeletal injury, fundamental research needed to understand the causes of occupational musculoskeletal injuries, and the research needed to provide the most effective prevention strategies. Evidence indicated that musculoskeletal injuries include the most costly types of occupational injuries and that they affect several million workers each year. Areas needing additional research include identifying hazardous job stressors, objectively measuring and quantifying job stress, identifying people at risk for musculoskeletal injuries, fundamental biomechanics, job hazard surveillance, and industrial planning and social/organizational issues.

2. Proposed National Strategies for the Prevention of Leading Work-Related Diseases and Injuries. Musculoskeletal Injuries. ***1986.***
NIOSH PUB NO: 89-112. 22 pp.
NTIS NO: PB90-170903 PRICE: Check NTIS

Four elements have been identified which contribute to death and disease through musculoskeletal injuries. These factors include environmental hazards, human biologic factors, behavioral factors or unhealthy lifestyles, and inadequacies in the existing health care and ancillary systems. Hazards to the musculoskeletal system associated with work are described as workplace traumatogens, a source of biomechanical stress stemming from job demands that exceed the worker's strength or endurance such as heavy lifting, or repetitive forceful manual twisting. Human biologic factors include the anthropometric or innate attributes that influence a worker's capacity for safely performing the job. Behavioral factors or unhealthy lifestyles refer to acquired behaviors or personal habits that increase the worker's risk of incurring musculoskeletal strain or injury. Inadequacies of the existing health care and ancillary systems include a lack of medical knowledge and appropriate training for health care personnel on the etiology, diagnosis, and treatment of musculoskeletal problems that result from biomechanical strain. Topics considered in this report include the musculo-skeletal conditions to be addressed, the scope of the national problem, the potential for prevention and control, the tactical areas of a national strategy for prevention, and the action plan.

3. Occupational Safety and Health Symposia. *1979.* Hadler N. **Arthritides: Effects of repetitive motion on the musculoskeletal systems.** pp. 120-128.
NIOSH PUB NO: 80-105. 178 pp.
NTIS NO: PB80-175706 PRICE: Check NTIS

The effect of pattern of usage on the structure and function of the hand was studied in a group of female worsted mill employees. The employees had engaged in the highly repetitive, stereotyped tasks of burling, winding, and spinning for at least 20 years. Data were obtained from clinical measurements of active ranges of motion, measurements of distal and proximal interphalangeal circumferences, and radiographs. Range of motion, malalignment, radiographic degenerative joint disease score, and derivatized circumference data were collected. Differences existed between the right and left hands, and most task related impairments were in the right hand. All three tasks were differentiated by patterns of usage of the women's hands. Guidelines for further testing of diseases associated with stereotyped, repetitive tasks are proposed by the author.

2. TESTIMONY *consists of both written comments and oral testimony presented before Congressional committees or at hearings convened by regulatory agencies. The following list of NIOSH testimony on cumulative trauma disorders is arranged in reverse chronological order.*

1. NIOSH [1993]. **Comments by R. Niemeier to DOL on the Occupational Safety and Health Administration Proposed Rule on Ergonomic Safety and Health Management, February 1 and August 24.** 66 pp.
(A copy of this testimony is in Part I, pages 15-88.)

2. NIOSH [1989]. **Congressional Testimony by L. Fine, Statement before the Employment and Housing Subcommittee, Committee on Government Operations, U.S. House of Representatives (Repetitive Trauma Disorders), June 6.** 6 pp.
NTIS NO: PB90-179250 PRICE: Check NTIS

This testimony concerned the activity of NIOSH in the field of repetitive trauma disorders. Such disorders were a class of musculoskeletal disorders involving damage to the tendons, tendon sheaths, and the related bones, muscles, and nerves of the hands, wrists, elbows, arms, feet, knees, legs, neck, and back. Diseases associated with such disorders included carpal tunnel syndrome, tendinitis, tenosynovitis, DeQuervain's Disease, low back pain, and vibration-induced Raynaud's syndrome. Such injuries have occurred as a result of repeated harm, not isolated accidents. Since 1984 the numbers of such reported injuries have doubled, exceeding 72,900 cases in 1987, and accounting for up to 39 percent of all occupational illnesses reported to OSHA in 1987. Manufacturing industries had the highest rate, with the five highest manufacturing industries being meatpacking, manufacturing and household appliances, rubber and plastic footwear, office and furniture fixtures, and motor vehicles and equipment. A manual was developed by NIOSH [see Part I, page 89] which identified cumulative trauma disorders (CTDs) of the upper limbs and identified risk factors, evaluated jobs and records and surveyed workers to determine if a problem was occurring, and provided guidelines for protecting workers in jobs that pose a serious risk. Current research programs in this area were described.

3. NIOSH [1984]. **Congressional Testimony by B. Johnson, Statement before the Subcommittee on Postal Personnel and Modernization, Committee on Post Office and Civil Service, U.S. House of Representatives (Carpal Tunnel Syndrome), June 8.** 11 pp.
NTIS NO: PB90-153792 PRICE: Check NTIS

This testimony concerned NIOSH research on carpal tunnel syndrome as an occupational disorder. The name, carpal tunnel, derives from the eight bones in the wrist called carpals which form a tunnel-like structure. The tunnel contains tendons which control finger movement and provide a pathway for the median nerve to reach sensory cells in the hand. Nerve compression results from various conditions. Repeated flexing and extension of the wrist causes the tendons to swell and thereby increases pressure in the bony tunnel which can pinch or trap the median nerve. Job tasks which involve highly repetitive manual acts or necessitate wrist bending or other stressful wrist postures are connected with incidents of carpal tunnel syndrome or related problems. Patients suffering from this syndrome lack the ability to sense cold or hot by touch and experience an apparent loss of strength in their fingers. Treatment may involve surgery or the use of antiinflammatory drugs. However, success in treatment has been limited. Jobs which have been identified as causing carpal tunnel syndrome have included the assembly of small parts and the manual inspection of manufactured products. Control measures focus on relieving excessive wrist deviations and arm and hand movements requiring force. Some tools have been redesigned.

of work stations and the use of fixtures to mount work at angles and reduce the need for the worker's hand to bend at the wrist. NIOSH studies of postal worker jobs and letter sorting machine operations were described.

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 superfacialis, 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 griped 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 sheathes 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 in 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 Renaut 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.

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 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.

6. HEALTH HAZARD EVALUATIONS *are studies of a workplace, such as a particular department in a factory, industrial plant, office building, or other worksite. The study is conducted by NIOSH in response to concerns expressed by employees, employee representatives, or employers, to find out whether there is a health hazard to employees caused by exposure to hazardous materials (chemical or biological contaminants) or working conditions (e.g., noise, heat, musculoskeletal stresses). The reports resulting from these studies are generally referred to as Hazard Evaluation and Technical Assistance (HETA) reports. Please note that each report discusses the conditions only at a specific worksite evaluated. The reports are listed alphabetically by company name.*

1. American Fuel Cell and Coated Fabrics Company, Magnolia, AR, ***May 1993.***
HETA NO: 90-246-2314. 71 pp.
NTIS NO: PB93-234037 PRICE: Check NTIS

In response to a request from a representative of the United Rubber Workers Union concerning chemical exposures, heat stress, and ergonomic problems occurring during the manufacture of coated rubber fuel cells by workers at the American Fuel Cell and Coated Fabrics Company (SIC-3069), Magnolia, Arkansas, an investigation was undertaken by NIOSH. The company manufactured fuel bladders for aircraft. Ergonomic assessments were performed in six areas; factors investigated included repetitive tasks, awkward postures, manual force requirements, and exposure to hand/arm vibration. Exposures to methyl ethyl ketone (MEK) ranged as high as 421 parts per million (ppm), exceeding the 300 ppm NIOSH short term exposure limit. Concentrations of 1,1,1-trichloroethane ranged from 293 to 878 ppm (NIOSH limit 350 ppm). Local exhaust systems were either absent or ineffective. The authors conclude that multiple health hazards existed at this facility, including overexposures to 1,1,1-trichloroethane and MEK, inadequate confined space entry program, ergonomic hazards, and inadequate personal protection. Mechanical and chemical trauma to the skin could occur in workers handling organic solvents, rubber adhesive, and rubber stock. The authors recommend measures for reducing solvent exposures, ergonomic problems, and heat stress, and for improving local exhaust ventilation, respirator selection, and personal protection.

2. Anchor Swan Division, Harvard Industries, Inc., Bucyrus, OH, ***August 1990.***
HETA NO: 87-428-2063. 23 pp.
NTIS NO: PB91-151720 PRICE: Check NTIS

In response to a request from the management of Anchor Swan Division (SIC-3079) of Harvard Industries, Inc., Bucyrus, Ohio, an investigation was made of the incidence of carpal tunnel syndrome (CTS) among employees at the site. The facility employed about 600 workers in the manufacture of automotive, industrial and garden hoses. A self-administered questionnaire concerning musculoskeletal symptoms was mailed to all employees. Responses indicated that employees in the formed hose department reported hand/wrist pain and other CTS related problems lasting for at least 4 days about twice as frequently as did workers in all other manufacturing departments, and ten times more often than did office workers and sales employees. An ergonomic evaluation of pin and cure jobs and other potentially high exposure jobs was conducted, including braiding in the industrial hose department, coupling in the plastic hose department, and cut, trim, pack and assembly in the formed hose department. Ergonomic analysis indicated that the pin and cure and brading jobs involved high levels of exposure to musculoskeletal stressors, that the coupling job had medium exposures, and that the cut, trim, pack and assemble had low to moderate exposures. The authors conclude that potential musculoskeletal hazards existed at the facility. The authors recommend specific measures to reduce the hazards.

3. Armco Composites, Hartford City, IN, ***February 1982.***
HETA NO: 81-143-1041. 27 pp.
NTIS NO: PB83-201426 PRICE: Check NTIS

Occupational exposures to cured resin particulates, styrene monomer, and ergonomic stresses at Armco Composites (SIC-3079), Hartford City, Indiana were investigated. About 120 production employees work on site. The study was a result of a confidential request and was performed on March 1 and 12, and July 20 and 21, 1981. Air samples were analyzed and medical interviews were conducted with 29 workers and an ergonomic study was performed. Personal breathing zone time-weighted-average concentrations of cured resin particulates peaked at 20.1 milligrams per cubic meter (mg/m3). Two samples exceeded the OSHA standard of 15 mg/m3. Styrene values were all below the OSHA standard of 435 mg/m3. Eighteen employees exhibited early signs of carpal tunnel syndrome (CTS) with symptoms of nocturnal numbness, swelling, and pain. Postures assumed during work included wrist flexion and extension, ulnar and radial deviation of the wrist, and open hand pinch. These postures have been associated with CTS. The authors conclude that a health hazard did exist from tasks involving repetitive hand and wrist movements. Exposures to cured resin particulates exceeded the nuisance dust criteria. Recommendations for decreasing the incidence of CTS and exposure to cured resin dusts are provided.

4. Bennett Industries, Peotone, IL, ***June 1990.***
HETA NO: 89-146-2049. 32 pp.
NTIS NO: PB91-115758 PRICE: Check NTIS

In response to a request from the International Chemical Workers Union an evaluation was undertaken of potential ergonomic hazards to workers involved in the production of metal and plastic containers at Bennett Industries (SIC-3070), Peotone, Illinois. Bennett Industries was involved in the manufacture of small to medium sized plastic and metal containers and employed 181 individuals. Several cases of carpal tunnel syndrome had been reported. An ergonomic evaluation of tasks in the plastics container division classified the jobs of shrink ring operator, cutter and handle attacher as high risk for the development of cumulative trauma disorders (CTDs). Jobs in the metals division were assessed as low to moderate risk. A questionnaire survey indicated that the prevalence of upper extremity pain was higher among workers in the plastics division compared to those in the metals division. Two job tasks, shrink ring operator and cutter, were identified with 83% of the reported CTD cases from January 1986 through June of 1989. These two job tasks involved only 15% of the workforce. The authors conclude that an upper extremity CTD hazard existed in the plastics containers division for these two jobs. The authors recommend that these tasks be redesigned.

5. Budd Company, North Baltimore and Carey, OH, ***June 1988***
HETA NOS: 84-459-1905 and 84-110-1905. 87 pp.
NTIS NO: PB89-120588 PRICE: Check NTIS

In response to confidential requests, a study was undertaken of possible hazardous working conditions at the Budd Company (SIC-3079) locations in North Baltimore and Carey, Ohio. Concern was expressed over worker exposure to isocyanates, methylene chloride (MeCl), and other chemicals. The Budd Company produced molded plastic automobile body parts and skis in compression mold presses from sheet molding compound. Primary sources of worker exposures to MeCl were in the prime wipe operation, and the use of MeCl as a general cleaning solvent at various jobs and locations. MeCl exposures ranged up to 239 ppm; NIOSH has recommended that levels be maintained at the lowest feasible level. All but one of the time-weighted-average exposures to styrene were below the recommended limits. Some association was found between MeCl exposure and neurological symptoms. There were also associations between work involving repetitive motion and hand and arm symptoms; jobs involving potential isocyanate exposure were also associated with irritative and respiratory symptoms. The authors conclude that a potential hazard existed from overexposure to MeCl. The authors recommend that measures be taken to reduce or eliminate MeCl exposures, that isocyanates be monitored continuously, and that jobs requiring repetitive motion be evaluated and redesigned.

6. Caldwell Manufacturing Company, Williamsport, MD, ***December 1990.***
HETA NO: 88-361-2091. 21 pp.
NTIS NO: PB91-197368 PRICE: Check NTIS

In response to a request from Caldwell Manufacturing Company (SIC-3442), Williamsport, Maryland, an evaluation was undertaken of carpal tunnel syndrome in assembly department workers. Caldwell Manufacturing employed about 65 hourly workers in the manufacture of window balance systems. A medical evaluation and an ergonomic evaluation were conducted. All of the assembly line jobs appeared to involve risk factors commonly associated with cumulative trauma disorders of the upper extremity: numerous hand/wrist manipulations, in combination with varying degrees of force and deviated wrist positions. At the time of the survey there were 5 medically confirmed cases of carpal tunnel syndrome and 6 additional possible cases among the 28 assembly workers. Two tasks were determined to represent the greatest risk: pulling springs to attach them to window liners, and hooking springs. In addition, defective material and pressure to increase production were identified as contributing factors. The authors conclude that a carpal tunnel syndrome hazard existed at the facility. The authors recommend specific measures to minimize the risk of carpal tunnel syndrome.

7. Cargill Poultry Division, Buena Vista, GA, ***November 1989.***
HETA NO: 89-251-1997. 51 pp.
NTIS NO: PB90-183989 PRICE: Check NTIS

In response to a request from OSHA, an evaluation was made of cumulative trauma disorders (CTDs) reported among employees at the Cargill Poultry Division (SIC-2016), Buena Vista, Georgia. The facility produced boneless chicken products for wholesale distribution. There were two shifts in operation. The first shift slaughtered, eviscerated, dissected, deboned, and packaged chickens. The second shift only dissected, deboned, and packaged. Most of the 490 workers were employed in the deboning department. There were 143 upper extremity (UE) CTDs recorded on the OSHA 200 logs during 1988. Questionnaires were given to 112 workers selected by job title. Based on the findings along with physical examinations of these 112 workers, a high prevalence of UE CTDs, particularly of the hand/wrist type, was found among current employees. There was a high employee turnover at this facility. Several steps had been taken by the company to curb CTD problems at this site. The authors conclude that an upper extremity cumulative trauma disorder hazard existed at this facility. The authors recommend specific measures to prevent or reduce morbidity.

8. Chef Francisco, Inc., Eugene, OR, ***January 1985.***
HETA NO: 83-053-1554. 16 pp.
NTIS NO: PB86-108362 PRICE: Check NTIS

A health hazard evaluation at Chef Francisco, Incorporated (SIC-2038), Eugene, Oregon, was conducted. The evaluation was requested by teamsters Local 670 due to a high incidence of musculoskeletal disorders among employees that were thought to be job-related. Ergonomic assessments of selected jobs in the soup, and new and old bakery departments were performed. The OSHA log of injuries and illnesses and company medical records were reviewed. Several jobs were identified that imposed stressful ergonomic demands such as unaided heavy lifting and transporting of loads, repetitive lifting that involved twisting of the trunk, excessive lifting and reach distances, and fatiguing postures and motions of the trunk and upper limbs. A total of 146 injuries were reported during the period January, 1982 to May, 1983. Of these, 24 were related to pulled muscles, bursitis, tendinitis, or arm numbness, 21 to hand and wrist problems, 21 to smashed appendages, and 20 to back strains. The authors conclude that manual material handling jobs were potentially hazardous to workers at the facility. Recommendations include providing safety and accident training for new employees and moving or redesigning equipment to reduce stress during heavy lifting or transporting of loads.

9. Devil's Lake Sioux Manufacturing Corporation, Fort Totten, ND, ***July 1987.***
HETA NO: 87-097-1820. 20 pp.
NTIS NO: PB88-153234 PRICE: Check NTIS

In response to a request from employees at the Devil's Lake Sioux Manufacturing Corporation (SIC-2352) located in Fort Totten, North Dakota, a study was made to determine a possible health hazard from n-hexane exposure and other organic solvents used in the manufacture of Kevlar combat helmets at this facility. Ten women working as edgers had been treated for carpal tunnel syndrome. Air samples revealed concentrations of xylene ranging from not detectable to 6.44 mg/m3, toluene ranging from 0.46 to 33.2 mg/m3, hexane ranging from 0.27 to 83.3 mg/m3, and methyl ethyl ketone ranging from 20.0 to 310 mg/m3. These levels were highest in the areas of the facility where edgers and glue spray booth operators worked. The author concludes that solvent exposures in these locations posed a potential health hazard. The carpal tunnel syndrome complaints appear to be related to ergonomic factors. The author recommends the substitution of less toxic materials in the workplace; applying proper engineering controls; improving local exhaust ventilation; providing protective clothing for workers; sampling of employees for organic solvent exposure at regular intervals; and informing the employees of all hazards inherent in their work.

10. Eagle Convex Glass Company, Clarksburg, WV, ***January 1990.***
HETA NO: 89-137-2005. 48 pp.
NTIS NO: PB91-108134 PRICE: Check NTIS

In response to a request from the management of Eagle Convex Glass Company (SIC-3231), Clarksburg, West Virginia, an evaluation was made of possible worker exposure to hazardous conditions resulting in occupational pneumoconiosis, hearing loss, and cumulative trauma disorders. The company produced a wide variety of speciality glass products for the automotive, furniture, and major appliance industries, employing 171 workers over 3 shifts. Hydrofluoric acid concentrations ranging from 0.34 to 3.0 mg/m3 were measured in the etching department. Analysis of the two solvents used in the decorating department indicated one contained mostly C10 to C11 alkyl substituted benzenes plus naphthalene. The following compounds were also identified: trimethylbenzene, methyl ethyl benzene, and indan. Noise levels in excess of the NIOSH recommended exposure level of 85 decibels-A, as a time-weighted-average, were found in some departments. Respirable dust levels ranged from 0.08 to 0.20 mg/m3. Symptoms consistent with hand/wrist, shoulder, and neck cumulative trauma disorders were noted among 20 to 30 percent of the workers in the decorating, processing, mirror and polishing departments. The authors conclude that some workers were potentially exposed to cumulative trauma, acid mists, and noise. The authors recommend specific measures, including work practices, ergonomic changes, a hearing conservation program, and a respiratory protection program.

11. Electric Machinery-McGraw Edison Company, Minneapolis, MN, ***April 1985.***
HETA NO: 81-466-1591. 37 pp.
NTIS NO: PB86-133758 PRICE: Check NTIS

Environmental and breathing zone samples were analyzed for amines, aliphatic aldehydes, boron trifluoride monoethylamine, epichlorohydrin , total volatile fluorides, formaldehyde, lead, methyl tetrahydrophthalic anhydride, and n-butyl glycidyl ether at Electric Machinery/McGraw Edison Company (SIC-3621), Minneapolis, Minnesota in December, 1981 and February, 1983. The surveys were requested by the union local because of irritative symptoms and respiratory problems reported by employees exposed to epoxy resin compounds and impregnated materials. Medical questionnaires were administered to 51 employees in the hand taping and pole winding departments and 57 comparisons. Formaldehyde, acetaldehyde, and lead were the only contaminants detected. All concentrations were below their OSHA standards. Skin rash and irritation, eye irritation, and throat irritation were the most frequently reported symptoms. Fifty-six percent of the exposed workers had evidence of carpal tunnel syndrome versus seven percent of the comparisons. The authors conclude that mucous membrane irritation and dermatitis are common among workers exposed to epoxy resins. A high prevalence of carpal tunnel syndrome was also found. Recommendations include reducing formaldehyde concentrations, using personal protective equipment and barrier creams, and maintaining proper work practices and good personal hygiene to minimize contact with epoxy resin materials.

12. FL Thorpe & Company, Inc., Deadwood, SD, ***August 1991.***
HETA NO: 90-273-2130. 34 pp.
NTIS NO: PB92-133321 PRICE: Check NTIS

In response to a request from FL Thorpe and Co. (SIC-3911), Deadwood, South Dakota, an evaluation was made of the upper extremity musculoskeletal disorders among their employees. The company manufactured gold jewelry for wholesale and retail distribution and has been in operation since 1878. The facility employed 115 people, 105 of whom were production employees. Work activities were video taped for analysis. Posture, force and static muscle contraction hazards were present in most jobs; two jobs involved exposure to hand/wrist vibration. All production employees completed a questionnaire designed to gather information on upper extremity musculoskeletal disorders. Of the 94 employees tested, 76 reported symptoms. Neck symptoms were reported most frequently (60%), but the hand/wrist area contained the most reported work-related musculoskeletal symptoms. The bright cut, wriggle, and wax departments had the highest prevalence of employees with these disorders. In 1989 and 1990, seven employees were diagnosed with carpal tunnel syndrome by local physicians. All were given at least 5 weeks off to recover from their carpal tunnel release surgery. The authors conclude that an upper extremity musculoskeletal hazard existed at this facility. The authors recommend the development of an ergonomics program, including specific engineering interventions.

13. Flexfab, Inc., Hastings, MI, ***September 1991.***
HETA NO: 89-267-2139. 48 pp.
NTIS NO: PB92-133230 PRICE: Check NTIS

In response to a confidential request, an evaluation was made of possible adverse health effects related to workplace exposures at Flexfab, Inc. (SIC-3052), Hastings, Michigan. Flexfab manufactured lightweight, flexible, nonmetallic parts for the automotive, trucking, aircraft, aerospace, and other industries as well as for the government and military. These products included flexible hose, ducts, and connectors made of silicones, neoprenes, and other elastomers. A workforce of approximately 285 hourly employees operated 3 shifts per day. The results of the study showed that the workers operating the mills in the rubber room were at risk of exposure to crystalline silica and that workers applying the sealant to flexible utility dusts were exposed to levels of tetrahydrofuran near the action limit. There was also a high incidence of upper extremity cumulative trauma disorders at this company. The authors conclude that the workers who operated the mills in the rubber room were at risk of exposure to crystalline silica. Workers who applied sealant to flexible utility ducts were exposed to tetrahydrofuran at levels near the action limit. The authors recommend that modifications be made to the ventilation system in an effort to reduce chemical and dust exposures. Specific measures to prevent and control cumulative trauma disorders are recommended.

14. Genie Home Products, Shenandoah, VA, *January 1987.*
HETA NO: 85-480-1771. 28 pp.
NTIS NO: PB87-205951 PRICE: Check NTIS

In response to a request from the International Union of Electronic, Electrical, Technical, Salaried and Machine Workers in Shenandoah, Virginia, an investigation was made of the health effects of repetitive motions required in many of the jobs at Genie Home Products, Inc. (SIC-3699), Shenandoah, Virginia. Remote control garage door openers, motorized remote control switches, heavy duty rotators, and antenna rotors were produced at this facility. Data were gathered concerning the number of injuries and workers' compensation reports as they related to job activities, symptoms, and illnesses for 1984, 1985, and January through March of 1986. The incidence of hand/wrist cumulative trauma disorders (CTDs) was significantly reduced over this period of time. Many of the job interventions undertaken at Genie during this time, particularly the torque limiters on the air powered nut drivers, represented not only technology and design that reduced stressful work postures, but also facilitated production. The author concludes that ergonomic improvements in jobs where workers had experienced CTDs have reduced the incidence of these disorders over the previous 2 years. Recommendations are made by the author for further reducing biomechanical demand on some specific jobs.

15. Harley-Davidson, Inc., Milwaukee, WI, *September 1990.*
HETA NO: 90-134-2064. 48 pp.
NTIS NO: PB91-184531 PRICE: Check NTIS

In response to a request from the Allied Industrial Workers, the International Machinist Unions, and management, an investigation was undertaken of possible hazardous working conditions at Harley-Davidson, Inc. (SIC-3751), Milwaukee, Wisconsin. The facility manufactured and assembled motorcycle parts 24 hours a day, 7 days a week. An ergonomic evaluation of job risk factors for musculoskeletal disorders at the flywheel milling area was performed, and employee medical record data were reviewed. The cumulative weight handled in lifting and transporting flywheels during the milling process was in excess of 14 tons for one worker and in excess of 9 tons for another worker. Data gathered indicated that potential musculoskeletal disorders could result at the elbow, shoulder, back, and hip during manual handling of the flywheel during the milling process. Job risk factors which may cause disorders included manual transport of the flywheel between milling processes, placement of the flywheel in the milling machinery, and removal of this part when milling was complete. Hand and wrist disorders may also result from exposure to hazardous vibration frequencies from a hand held power grinder used to remove metal burrs from milled flywheels and during manual tightening of this part onto the index milling machine. The authors conclude that musculoskeletal hazards existed for the upper limbs and back.

16. Harvard Industries, Inc., Trim Trends Division, Bryan, OH, ***July 1992.***
HETA NO: 91-086-2235. 35 pp.
NTIS NO: PB93-119915 PRICE: Check NTIS

In response to a request from management and the Allied Industrial Workers of America, an investigation was made of possible hazardous working conditions in the Trim Trends Division of Harvard Industries (SIC-3442), Bryan, Ohio. Concern was expressed about exposure to welding fumes and grinding dust, and repetitive motion. The company manufactured automobile parts including window sashes, spinners (transmission parts), stampings, and door beams. There were 230 hourly employees at the time of the site visit. Sample concentrations for iron, magnesium, manganese, and zinc were below existing guidelines and standards. One personal breathing zone sample for a welder contained 0.167 mg/m3 copper fume, while the NIOSH recommended exposure limit was 0.1 mg/m3. Videotape of work activities indicated that many of the production jobs exposed employees to risk factors commonly associated with upper extremity cumulative trauma disorders including repetitive hand/wrist movements and excessive manual force application. The greatest risk was associated with the grinding task during which workers were also exposed to vibration. The authors conclude that a potential health hazard for upper extremity cumulative trauma disorders existed for workers in the welding and grinding areas. The authors recommend specific measures to reduce the ergonomic risk factors and improve safety conditions.

17. ICI Americas, Inc., Charlestown, IN, ***May 1983.***
HETA NO: 83-142-1431. 11 pp.
NTIS NO: PB85-184125 PRICE: Check NTIS

An evaluation of the incidence of ganglionic cysts and tendonitis at ICI Americas, Incorporated (SIC-3483), Charlestown, Indiana, was conducted in May 1983. The request for evaluation was made by the International Chemical Workers Union due to the occurrence of nine cases of ganglionic cysts and two of tendonitis among quality assurance personnel working on load lines 5A, 6A, 6B, and 2B. The evaluation consisted of observing work practices and job tasks, employee interviews, and a questionnaire survey. Jobs on load lines 5A, 6A, and 6B were the most physically stressful. The most stressful work posture involved carrying 28 pound ammunition charges with both hands at the end of the charge. The proportion of employees reporting somatic complaints involving upper extremities, back, and lower extremities ranged from 19 to 42 percent. Thirty-one percent of the employees reported a lesion diagnosed as a ganglionic cyst. The authors conclude that quality assurance personnel perform certain tasks that may be associated with the development of cumulative trauma disorders such as ganglionic cyst. Recommendations include carrying the charges by cradling them, and management evaluation of production personnel for biomechanical health problems.

18. ICI Americas, Inc., Indiana Army Ammunition Plant, Charlestown, IN, ***December 1987.***
HETA NO: 85-534-1855. 30 pp.
NTIS NO: PB88-204524 PRICE: Check NTIS

In response to a request from the International Chemical Workers Union, a study was made of carpal tunnel syndrome, ganglionic cysts, and tendonitis of the wrists in production workers at ICI Americas, Inc. ammunition facility (SIC-3483) in Charlestown, Indiana. About 1800 workers were employed in the assembly of solid propellant charges used to propel projectiles. Questionnaires were completed by 463 production workers. Workers in the assembly, lace, and tie job classification had the highest prevalence of upper extremity symptoms. Ergonomic evaluations were performed on the six jobs having the highest incidence of upper extremity symptoms. Analysis of the video tapes indicated the tying of pull straps on the propellant charges to be one of the most difficult tasks performed by these workers. Movements were highly repetitive, caused awkward and forceful manipulations of the hand and wrist, and involved many factors causally related to cumulative trauma disorders. Additional problems included excessive reach distances, improper work height, and improper seated work postures. The authors conclude that this production work is associated with a high prevalence of musculoskeletal disorders. The authors recommend specific improvements in each job. Training sessions should be conducted to instruct the workers how to accomplish their given tasks with less bodily strain. All hand and wrist injuries should be reported to their employer and accurate records should be kept.

19. John Morrell & Co., Sioux Falls, SD, *April 1989.*
HETA NO: 88-180-1958. 42 pp.
NTIS NO: PB90-128992 PRICE: Check NTIS

In response to a request from OSHA, technical assistance was rendered in evaluating possible harmful working conditions at John Morrell and Company (SIC-2011), Sioux Falls, South Dakota. This facility employed about 2000 workers in the production of beef and pork products, predominantly for wholesale distribution. Cumulative trauma disorders (CTDs) were diagnosed 880 times in a 1-year period, for an upper extremity CTD incidence rate of 41.7 per 100 full-time workers per year, which was high when compared to the 6.7 incidence rate reported for the meat packing industry. Videotapes were made of 185 jobs for ergonomic evaluation. Based on these tapes, 14 jobs were considered to be low risk, 114 jobs were intermediate risk, and 57 jobs were high risk for developing upper extremity CTDs. The strongest predictor of hand/ wrist CTDs was vibration, followed by force as measured by peak effort. A higher than expected incidence of carpal tunnel syndrome was also diagnosed. The authors conclude that an upper extremity CTD hazard existed at the time of the survey. The authors recommend engineering changes to reduce the job demands of high repetition, high force, and extreme postures. Administrative changes were suggested to reduce the hazards including training, job rotation, rest pauses, and changes in the temperatures of the work rooms. Other recommended changes included employee education, early detection, slowing the work pace on returning to work, and the institution of a medical reevaluation of the capability of the worker to return to work.

20. KP Manufacturing Company, Minneapolis, MN, *March 1983.*
HETA NO: 81-375-1277. 85 pp.
NTIS NO: PB84-209717 PRICE: Check NTIS

The existence of excessive musculoskeletal demands associated with particular jobs was investigated at KP Manufacturing Company (SIC-3499), Minneapolis, Minnesota in September 1981 and February 1982. The survey was requested by management and the United Electrical, Radio and Machine Workers of America Union Local 1139 on behalf of 157 employees. Nineteen complaints of hand, wrist, and forearm problems were recorded in a 2-year period. These were diagnosed as carpal tunnel syndrome. Eight employees required surgery. Nine of the complaints were reported by production workers, while ten were in assembly. Production complaints could not be attributed to any specific job. A walk-through tour was conducted to identify problem areas. Still photographs and motion pictures were taken of problem areas for further evaluation. After reviewing the films, an in-depth ergonomic study of 15 jobs was performed. Operators were forced to assume fatiguing postures. Excessive radial deviation of the hand and excessive hand forces were required in some jobs. Other problems were reaching excessive distances and performing excessive bending motions. The author concludes that poor orientation of worker position to machines and parts presented risks to the musculoskeletal system. Risk factors associated with overexertion should be reduced.

21. Longmont Turkey Processors, Inc., Longmont, CO, ***April 1988.***
NO: 86-505-1885. 32 pp.
NTIS NO: PB89-106546 PRICE: Check NTIS

In response to a request from the United Food and Commercial Workers Union Local 7, an evaluation of possible hazardous working HETA conditions was made at the Longmont Turkey Processors, Inc. (SIC-2017), Longmont, Colorado. The facility processed live turkeys and some partially processed chilled or frozen birds. Workers were concerned about carpal tunnel syndrome (CTS) and other musculoskeletal injuries. Injuries to personnel were reviewed, based on OSHA logs and facility medical logs. Job types were classified as high, intermediate, or low in risk for incurring a repetitive trauma injury due to job performance. Persons employed in boning, bird hanging, evisceration, production, and raw manufacturing were more likely to experience difficulties than those who fell in jobs classified as low risk. Video tapes of 14 production jobs in the eviscerating department and 22 in the boning and specials lines were analyzed. One primary risk factor involved the number of cuts made per day. Considerable under-reporting of incidents was noted in the OSHA logs. The authors conclude that identifiable groups of workers are at greater risk for developing carpal tunnel syndrome and repetitive strain disorders. The authors recommend specific actions which should be taken to control biomechanical hazards.

22. Los Angeles Times, Los Angeles, CA, ***January 1993.***
HETA NO: 90-013-2277. 126 pp.
NTIS NO: PB93-188456 PRICE: Check NTIS

In response to a request from the management of the Los Angeles Times (SIC-2711), an investigation was made of the occurrence of work-related musculoskeletal disorders among workers using video display terminals at the facilities located in Los Angeles and in Costa Mesa, California. Of 1050 eligible employees, 973 participated in the study. Symptoms meeting the case definition for at least one upper extremity work-related disorder were reported by 395 of the participants. The most common symptoms were problems of the neck (26%), the hand/wrist (22%), the shoulder (17%), and the elbow (10%). The department with the largest number of employees reporting symptoms was the Circulation Department followed in decreasing order of frequency by the Accounting and Finance Department, Classified Department, and Editorial Department. Women were more likely to report symptoms. The authors conclude that a high prevalence of possibly work-related musculoskeletal disorders and symptoms was observed. The authors recommend specific measures to lessen this problem at these work locations.

23. Miller Electric Company, Woonsocket, RI, ***June 1982.***
HETA NO: 81-217-1086. 23 pp.
NTIS NO: PB83-202119 PRICE: Check NTIS

In June of 1981, a preliminary ergonomic evaluation at the Miller Electric Company (SIC-364), Woonsocket, Rhode Island, was conducted. During prior surveys, cumulative strain disorders had been reported. The workforce comprises 415 production workers, who are mostly female. Observation of jobs revealed that repetitive flexion and extension of the wrist, radial and ulnar deviations, and pinching were commonplace. Stressful motions in particular jobs included: wrist flexion while inserting blades into the fixture on the Miller Molder; extension and ulnar deviation of wrists while performing the blading operation; and open hand pinching while packing light socket assemblies. The author concludes that a hazard of developing musculoskeletal disorders of the hand and wrist existed. These disorders are likely to continue unless work practice modifications are implemented. Biochemical stresses could be reduced by workplace redesign and administrative controls.

24. Minneapolis Police Department, Minneapolis, MN, *November 1986.*
HETA NO: 84-417-1745. 10 pp.
NTIS NO: PB87-185591 PRICE: Check NTIS

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 have adequate surface areas for the typewriter and documents being processed.

25. Newsday, Inc., Melville, NY, *May 1990.*
HETA NO: 89-250-2046. 76 pp.
NTIS NO: PB91-116251 PRICE: Check NTIS

In response to a request from the Graphics Communication International Union and the Management of Newsday, Inc. (SIC-2711), Melville, New York, a study was undertaken of cumulative trauma disorders (CDT) among employees. Newsday published a daily newspaper and employed about 4,600 persons at several offices on Long Island, New York, and in New York City. A survey was conducted to estimate the prevalence of CTD among the employees, determine whether CTD symptoms occurred more often in particular jobs or departments, and determine whether there was any relation between the use of computer keyboards or other job-related factors and CTD symptoms in this group of workers. Of the 834 participating employees, 331 (40%) reported symptoms consistent with upper extremity CTDs during the past year. The most prevalent were hand/wrist symptoms followed by symptoms of the neck, elbows/forearm, and shoulder. The authors conclude that a hazard for upper extremity cumulative trauma disorders existed at these facilities. The authors recommend establishing a joint labor management committee to oversee ergonomic control measures, early recognition of symptoms, and evaluation of the effectiveness of interventions.

26. Perdue Farms, Inc., Lewiston and Robersonville, NC, *February 1990.*
HETA NO: 89-307-2009. 38 pp.
NTIS NO: PB91-104620 PRICE: Check NTIS

In response to a request from the North Carolina Department of Labor for technical assistance in evaluating cumulative trauma disorders (CTDs) of the neck and upper extremity, an investigation was made at two Perdue Farms facilities (SIC-2016) located in North Carolina at Lewiston and Robersonville. Concerns included repetitive and forceful motions and/or extreme and awkward postures of the upper extremity. Perdue Farms, Inc. produced and packaged boneless chicken products, chicken parts, and whole chickens for wholesale distribution. About 2,600 workers were employed at the Lewiston facility, processing over 420,000 chickens/day. About 550 workers were employed at the Robersonville facility, processing over 120,000 chickens/day. Jobs were classified into higher exposure (HE) or lower exposure (LE) groups. Questionnaires, and physical examinations were administered to groups of workers. Questionnaire results indicated that 36% of the 174 employees participating at the Lewiston site had evidence of work-related CTDs, largely involving the hand and/or wrist. Workers in HE jobs were 4.4 times more likely than employees in the LE jobs to have these difficulties. At the Robersonville site, 20 percent of the 120 participants had similar findings. The author concludes that a neck and upper extremity CTD hazard existed at these facilities. The author recommends some specific measures to prevent and manage CTDs at both sites.

27. Point Adams Packing Company, Hammond, OR, ***April 1986.***
HETA NO: 83-251-1685. 11 pp.
NTIS NO: PB87-108312 PRICE: Check NTIS

Management of Point Adams Packing Company (PAPCO) (SIC-0912), Hammond, Oregon initiated a request for an evaluation concerning the excessive number of cases of carpal tunnel syndrome, tendinitis, and other musculoskeletal disorders suffered by filleters, trimmers, and slimers at the fish filleting facility. An ergonomic evaluation was conducted on June 6 and 7, 1983; 145 production workers were employed at that time. Based on observations and a review of videotapes and still photographs, the authors conclude that a combination of factors seems to be associated with the musculoskeletal injuries afflicting these workers. These included: work rate, awkward hand and wrist deviations, use of gloves that compromise grip strength, cold temperature, use of high muscular forces for prolonged periods, excessive workplace reaches and heights that stress shoulder muscles, and improper tool handle design. Recommendations are offered for workplace modification, tool redesign, and training with the ultimate goal of reducing or eliminating biomechanical hazards associated with the development of cumulative trauma disorders.

28. Schnuck's, National, & Dierberg's Supermarkets, St. Louis, MO, ***April 1993.***
HETA NO: 92-294-2301. 23 pp.
NTIS NO: PB94-110376 PRICE: Check NTIS

In response to a request from Local 655 of the United Food and Commercial Workers Union, an investigation was made into biomechanical hazards at the checker unload workstations in supermarkets (SIC-5411) in St. Louis, Missouri. An ergonomic evaluation was undertaken at three supermarket chains (Dierberg's, Schnuck's, and National). Videotaping and photography were performed of cashier work activities at each of these locations. The dimensions of the checkout stand and the grocery carts were also determined. All three chains required the cashier to unload the customer's cart for scanning. Two chains used shallow carts designed for cashier unload operations, while one used conventional carts. An analysis was undertaken of cashier postures and movements during grocery scanning activities. Data were compared to similar information obtained from workers where grocery items were unloaded by the customer and placed on conveyors. The use of checker unload workstations increased the normal degree of stress on the cashier, which may exacerbate the risk of musculoskeletal disorders associated with this job. The frequency of long reaches was increased, as were awkward shoulder postures and lifts. The authors conclude that a health hazard existed at these supermarkets from excess biomechanical stress due to the use of checker unload checkstands. The authors recommend that such checker unload stations be replaced by customer unload stations.

29. Schulte Corporation, Cincinnati, OH, ***September 1991.***
HETA NO: 90-232-2138. 23 pp.
NTIS NO: PB92-133263 PRICE: Check NTIS

In response to a confidential request from employees of the Schulte Corporation (SIC-3496), Cincinnati, Ohio, an evaluation was undertaken of complaints of chest tightness, itching, metallic taste in the mouth, and discharge of black dust from the noses of workers in the machine shop of the facility. The facility was involved in the manufacturing and shipping of epoxy coated steel wire shelving. Total dust samples taken in the breathing zone of the workers ranged from 0.49 to 4.78 mg/m3, well below the permissible limits. Respirable dust samples ranged from 0.05 to 0.43 mg/m3. Exposures to nitrogen oxides were well below acceptable limits. Aldehydes were not detected in samples evaluating exposure to two resistance welders. The NIOSH ceiling level of 0.1 part per million for ozone was exceeded near welders. Six workers interviewed reported symptoms including black nasal discharge, headaches, sore throat, cough, hoarseness of voice, metallic taste and chest tightness. There was a potential ergonomic problem due to repetitive wrist motion. The authors conclude that a potential hazard from ozone exposure existed. The authors recommend measures to reduce exposures and development of a program for the prevention of cumulative trauma.

30. Scott Molders, Inc., Kent, OH, *July 1992.*
HETA NO: 91-003-2232. 21 pp.
NTIS NO: PB93-119360 PRICE: Check NTIS

In response to a request from the Allied Industrial Workers of America, a health hazard evaluation was conducted at Scott Molders (SIC-3089), Kent, Ohio regarding ergonomic concerns and potential exposures to ammonia, fibrous glass, formaldehyde, phenol, and styrene. The company employed about 70 workers in molding plastic and fibrous glass parts of automotive, military and custom order clients. Workers were observed and videotaped in the molding and finishing areas. The major upper extremity stressors of these jobs were postural and muscular force demands which occur while performing the following task elements: unloading parts from molding machines and breaking or cutting off the excess plastic from parts; filing, reaming and sanding flashing from parts; reaching to activate press control buttons; and reaching to dispense completed parts into boxes or barrels. A general ergonomic risk factor for all workers was prolonged standing. Eight of 21 workers gave histories consistent with cumulative trauma disorders, and 4 workers had undergone surgery for chronic carpal tunnel syndrome. All air quality readings taken indicated that the levels of fibrous glass molding materials and other chemicals were within acceptable limits. The authors conclude that there were exposures to several postural and muscular force stressors. There were no overexposures to the chemicals. The authors recommend redesigning several work areas to minimize ergonomic stressors and reduce exposure to the chemical substances.

31. Shoprite Supermarkets, NJ-NY, *January 1991.*
HETA NO: 88-344-2092. 63 pp.
NTIS NO: PB91-212431 PRICE: Check NTIS

In response to a request from the United Food and Commercial Workers Union in Clifton, New Jersey, NIOSH conducted an evaluation of possible hazardous working conditions at the Shoprite Supermarkets (SIC-5411) located in New Jersey and New York. The nature of the problem involved cumulative trauma disorders (CTDs) among employees serving as checkers. CTDs occurred in workers whose jobs required repetitive exertion, most often of the upper extremities. Multiple logistic regression (MLR) analysis revealed elevated odds ratios for checkers compared to noncheckers for all parts of the upper extremities. However, only the associations for shoulder and hand were statistically significant. MLR analysis of the checkers alone revealed a statistically significant dose response relationship between checking and disorders for all parts of the upper extremities. Differences were also noted between prevalences of disorders in those using different checkstand designs. The ergonomic analysis examined repetitiveness, posture and efficiency of movements for the different checkstand designs. The total repetitions per hour based on normal customer orders ranged from 1,432 to 1,782 for the right hand and 832 to 1,260 for the left hand. Multiple awkward postures were detected involving all parts of the upper extremities. Recommendations were made for ergonomically improving checkstand design as well as temporarily altering the existing checkstand designs.

32. Standard Publishing Company, Cincinnati, OH, ***May 1989.***
HETA NO: 84-187-L1966. 11 pp.
NTIS NO: PB89-230528 PRICE: Check NTIS

In response to a request from the management of the Standard Publishing Company, Cincinnati, Ohio, an investigation was made of working conditions at the site which might be contributing to the incidence of carpal tunnel syndrome (CTS) and ganglionic cysts among employees engaged as machine helpers in the bindery area. A self-administered questionnaire was completed by 75 full-time employees in the bindery area to determine the frequency of wrist and forearm symptoms occurring in the preceding month. Questions also addressed specific diagnoses which had been rendered for certain wrist conditions. Eighteen workers were medically evaluated, and videotapes were made of these workers for ergonomic evaluation. Of four individuals identified as potential CTS cases, only one was considered to actually have CTS based on both initial and follow-up questionnaires and the results of a physical examination. In a subsequent review of OSHA 200 logs for 1978 through March of 1984, 17 conditions associated with cumulative or repeated trauma were uncovered among bindery workers. The author recommends that specific measures be taken to reduce postural stress.

33. The Donaldson Company, Inc., Dixon, IL, ***April 1983.***
HETA NO: 81-409-1290. 25 pp.
NTIS NO: PB84-209758 PRICE: Check NTIS

Reports of carpal tunnel syndrome (CTS) and possible polyneuropathy among employees at Donaldson Company, Incorporated (SIC-3714), Dixon, Illinois were evaluated in August, 1981 and January and February, 1982. Evaluation was requested by Teamsters Local 455. A detailed ergonomic evaluation was conducted followed by air sampling for perchloroethylene (PCE), vinyl chloride (VC), and freons. Company medical records of CTS cases over a 5-year period were reviewed. A medical survey of current employees was also conducted. A VC concentration of 0.29 parts per million (ppm) was found in an area sample which was lower than the NIOSH recommended ceiling. Air concentrations of individual freons ranged from 4.2 to 7.4 ppm which were considerably below OSHA standards. Three-hour time-weighted-average air concentrations ranged from 12.6 to 76.2 ppm; 15-minute ceiling concentrations were 14.2 to 103.1 ppm. Eighteen cases of CTS were diagnosed during the 5-year medical record review. The medical survey suggested CTS symptoms in 92 of 96 current employees; 6 reported numbness or tingling in the feet. Work practices in several departments which might induce or exacerbate CTS were identified. The investigators conclude that a potential health hazard from exposure to airborne PCE exists and recommend changes in work practices and tool design.

34. United States Postal Service, General Mail Facility, Denver, CO, ***July 1993.***
HETA NO: 92-0073-2337. 21 pp.
NTIS NO: PB94-133824 PRICE: Check NTIS

In response to a confidential request from employees working at the Denver General Mail Facility (SIC-4311) in Colorado, an evaluation was undertaken of ergonomic hazards associated with the use of two types of automated mail processing machines, the Bar Code Sorter (BCS) and the Optical Character Reader (OCR). Subsequent requests asked that the study be expanded to include the Delivery Bar Code Sorter (DBCS), the Pitney-Bowes (PB) OCR, and the stool or rest bar used in the manual letter casing area. The OCR and sorters required a worker to feed mail and a worker to sweep mail out. Several hazards were identified which put the users of the equipment at risk for low back and upper extremity musculoskeletal disorders. The tasks were moderately repetitive, and workers had to work in awkward positions when operating these automated mail processing machines. Design flaws at the DBCS sweeper position were deemed to be particularly hazardous. The authors recommend that several of the positions be automated, particularly the sweeping positions linked to mail processing machines. Changes should be made to eliminate extreme trunk flexion while retrieving trays of mail and to minimize the number of reaches to the tray racks while sweeping.

35. U.S. Army Corps of Engineers, North Central Division, Chicago, IL, *January 1992.*
HETA NO: 90-385-2173. 36 pp.
NTIS NO: PB92-176809 PRICE: Check NTIS

In response to a request from the Deputy Commander of the U.S. Army Corps of Engineers (SIC-4441), North Central Division, a study was made of possible hazards to maintenance and construction workers. The work force in question was involved in maintaining 18 dams and 22 lock chambers on the Mississippi River from Saverton, Missouri, to Guttenberg, Iowa and also on the Illinois Waterway from La Grange Lock and Dam to Chicago, Illinois. Data gathered through on site studies indicated that potential musculoskeletal disorders could result at the elbow, shoulder, back and hip during the manual material handling in the maintenance shop in Peoria, Illinois, at the Lock and Dam Facility among the lock persons and during lock maintenance and repair. Job tasks that involved ergonomic risk factors included manual handling and transport during a roller repair operation, tying off of barge ropes while barges are locking through, and grinding during repair of lock gates. Hand and wrist disorders may also result from exposure to vibration from a hand held power sander. The author concludes that musculoskeletal hazards existed for the upper limbs and back. The author recommends measures to lower the ergonomic risks to the workers.

36. U.S. West Communications, Phoenix, AZ, Minneapolis, MN, and Denver, CO, *July 1992.*
HETA NO: 89-299-2230. 61 pp.
NTIS NO: PB93-119329 PRICE: Check NTIS

In response to a request from US West Communications (SIC-4813) and the Communications Workers of America, an evaluation was undertaken of the effects of the use of video display terminals on the musculoskeletal systems of Directory Assistance Operators. A cross sectional study was made of 533 workers employed by the company in Phoenix, Minneapolis/St. Paul, and Denver. Information on the type of workstations, job requirements, and worker health was gathered. Two types of musculoskeletal outcomes were identified for analysis: potential work-related upper extremity musculoskeletal disorders defined by physical examination and questionnaire, and upper extremity musculoskeletal symptoms defined by questionnaire alone based on a cumulative score of symptom duration, frequency and intensity. The authors conclude that there was a high prevalence of potential work-related musculoskeletal disorders and symptoms. Factors associated with these disorders include demographics, prior medical conditions, work practices, psychosocial aspects of the workplace, and electronic performance monitoring. Most of the physical workstations observed were of high ergonomic quality. The psychosocial work environment may be related to the occurrence of work-related upper extremity musculoskeletal symptoms and disorders. The authors recommend specific measures to improve working conditions and possibly prevent and control musculoskeletal disorders.

37. WBZ-TV News, Boston, MA, *July 1994.*
HETA NO: 93-0860-2438. 12 pp.
NTIS NO: PB95-147260 PRICE: Check NTIS

In response to a confidential request from employees of WBZ-TV News, Boston, Massachusetts, a study was undertaken of carpal tunnel syndrome (CTS) and other musculoskeletal problems among videotape editors. The medical component of the health hazard evaluation included a review of Occupational Safety and Health Administration injury and illness logs (OSHA 200 logs), pertinent medical records, and confidential interviews with employees. The ergonomic assessment was accomplished via walk-through inspections and videotape evaluation. Four medically-confirmed cases of carpal tunnel syndrome occurred among employees at this workplace within the past two years. Two CTS cases occurred among the eight videotape editors. Risk factors that have been associated with carpal tunnel syndrome and other musculoskeletal disorders were observed to be present in the videotape editing jobs. Several sources of musculoskeletal stress associated with news editing were identified, including suboptimal workstation and chair design. In addition, stressful work organization and psychosocial factors, including working under deadline pressure, and a lack of control over the workload, the work environment, and equipment were also identified. Recommendations include engineering and administrative controls, and the creation of a joint labor/management committee. Because of the upcoming move into a new facility, a unique opportunity exists to consider ergonomic principles when designing the new videotape editing rooms and workstations.

38. Western Publishing Co., Racine, WI,
June 1988.
HETA NO: 84-240-1902. 40 pp.
NTIS NO: PB89-120562 PRICE: Check NTIS

In response to a request from the management of the Western Publishing Company Inc. (SIC-2732), Racine, Wisconsin, a study was made of cases of carpal tunnel syndrome (CTS) among workers. The company printed, bound, and packaged books, along with other printed materials including pamphlets, coupons, and playing cards. Ergonomic stress levels were compared for 11 workers diagnosed with probable CTS and 22 persons without musculoskeletal symptoms; CTS cases had higher stress scores for all 4 body areas assessed. A review of the work-related injuries and illnesses at the facility identified a group of 25 cases with disorders associated with repeated trauma during the period from 1979 through 1984. The highest number of these injuries occurred in the cylinder press department; work in that area was repetitive, excessive force was required, postures were awkward, and vibrating tools were used. The rate of disorders associated with repeated trauma was seven times higher at this facility than at similar firms. The authors conclude that there was an association between work-related stresses and the development of cumulative trauma disorders at this facility. The authors recommend that action be taken to control ergonomic factors that may contribute to the rate of cumulative trauma disorders.

39. Yorktowne, Inc., Mifflinburg, PA,
August 1990.
HETA NO: 88-384-2062. 30 pp.
NTIS NO: PB91-152082 PRICE: Check NTIS

In response to a request from company management, an on site visit was made to Yorktowne, Inc. (SIC-5712), a cabinet manufacturing company located in Mifflinburg, Pennsylvania. A high number of musculoskeletal disorders had been reported among the workers at that location. Approximately 450 full-time workers were employed at the site. A significant amount of work involved pushing, pulling, lifting, and carrying heavy materials. Selected jobs in raw materials handling, sawing, frame assembly, sanding and painting, cabinet assembly, and packaging/shipping departments were subjected to ergonomic assessments. Several jobs were identified that imposed potentially stressful biomechanical demands on the workers. These demands included fatiguing postures, repetitive lifting that involved twisting of the trunk and excessive reach distances, and repetitive motions of the trunk and upper limbs. Most injuries (70%) occurred during a worker's first year of employment. The authors conclude that certain tasks were potentially hazardous to workers at the facility. The authors recommend the following: offering basic safety training to new employees, and moving or redesigning equipment to reduce stress during heavy lifting, pushing, and transporting of loads, and while performing repetitive motion tasks.

B. SELECTED NON-NIOSH PUBLICATIONS

This section includes references on cumulative trauma disorders selected from non-NIOSH sources. Copies of the references can be obtained from university or public libraries.

Amadio P [1985]. Pyridoxine as an adjunct in the treatment of carpal tunnel syndrome. Journal of Hand Surgery *10A*(2):237-241.

Armstrong T, Castelli W, Evans F [1984]. Some histological changes in carpal tunnel contents and their biomechanical implications. Journal of Occupational Medicine *26*(3):197-201.

Armstrong T, Fine L, Goldstein S, Lifshitz Y, Silverstein B [1987]. Ergonomics considerations in hand and wrist tendinitis. The Journal of Hand Surgery *12A*(5)Part 2:830-837.

Armstrong T, Foulke J, Joseph B, Goldstein S [1982]. Investigation of cumulative trauma disorders in a poultry processing plant. American Industrial Hygiene Association Journal *43*(2):103-116.

Armstrong T, Radwin R, Hansen D, Kennedy K [1986]. Repetitive trauma disorders: job evaluation and design. Human Factors *28*(3):325-336.

Arndt R [1987]. Work pace, stress and cumulative trauma disorders. Journal of Hand Surgery *12A*(2)Part 2:866-869.

Bauman T, Gelberman R, Murbarak S, Garfin S [1981]. The acute carpal tunnel. Clinical Orthopaedics and Related Research *156*(May):151-156.

Birbeck M, Beer T [1975]. Occupation in relation to the carpal tunnel syndrome. Rheumatology and Rehabilitation *14*(4):218-221.

BLS [1993]. Occupational injuries and illnesses in the United States by industry, 1991. Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics, Bulletin 2424.

BLS [1994]. Workplace injuries and illnesses in 1993. Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics, USDL 94-600.

Brain W, Wright A, Wilkinson M [1947]. Spontaneous compression of both median nerves in the carpal tunnel. The Lancet March:6443-6445.

Bruner J [1972]. Carpal tunnel syndrome. The Hand *4*(3):220-223.

Cannon L, Bernacki E, Walter S [1981]. Personal and occupational factors associated with carpal tunnel syndrome. Journal of Occupational Medicine *23*(4):255-258.

Das S, Brown H [1976]. In search of complications in carpal tunnel decompression. The Hand *8*(3):243-249.

Dionne E [1984]. Carpal tunnel syndrome. Part I - the Problem. National Safety News *129*(3):42-45.
(A copy of this article is in Part I, pages 143-146.)

Dionne E [1984]. Carpal tunnel syndrome - Part II: Some Answer. National Safety News *129*(4):53-58.
(A copy of this article is in Part I, pages 147-152.)

Duncan K, Lewis R, Foreman K, Nordyke M [1987]. Treatment of CTS by members of the American Society for Surgery of the Hand: results of a questionnaire. The Journal of Hand Surgery *12A*(3):384-390.

Feldman R, Travers P, Chirico-Post J, Keyserling W [1987]. Risk assessment in electronic assembly workers: carpal tunnel syndrome. Journal of Hand Surgery *12A*(2) Part 2:849-855.

Feldman, R Goldman, R, Keyserling, W [1983]. Classical syndromes in occupational medicine. Peripheral nerve entrapment syndromes and ergonomic factors. American Journal of Industrial Medicine *4*(5):661-681.

Fissette J, Onkelinx A [1979]. Treatment of carpal tunnel syndrome. Comparative study with and without epincurolysis. The Hand *11*(2):206-210.

Franklin G, Haug J, Heyer N, Checkoway H, Peck N [1991]. Occupational carpal tunnel syndrome in Washington State, 1984-1988. American Journal of Public Health *81*(6):741-746.

Franzblau A, Werner R, Valle J, Johnston E [1993]. Workplace surveillance for carpal tunnel syndrome: a comparison of methods. Journal of Occupational Rehabilitation *3*(1):1-14.

Gelberman R, Hergenroeder P, Hargens A, Lundborg G, Akeson W [1981]. The carpal tunnel syndrome. A study of carpal canal pressures. The Journal of Bone and Joint Surgery *63A*(3):380-383.

Gelberman R, Rydevik B, Pess G, Szabo R, Lundborg G [1988]. Carpal tunnel syndrome. A scientific basis for clinical care. Orthopedic Clinics of North America *19*(1):115-124.

Green D [1984]. Diagnostic and therapeutic value of carpal tunnel injection. The Journal of Hand Surgery *9A*(6):850-854.

Hagberg M, Morgenstern H, Kelsh M [1992]. Impact of occupations and job tasks on the prevalence of carpal tunnel syndrome. Scandinavian Journal of Work, Environment and Health *18*(6):337-345.

Hagberg M, Nystrom A, Zetterlund B [1991]. Recovery from symptoms after carpal tunnel syndrome surgery in males in relation to vibration exposure. The Journal of Hand Surgery *16A*(1):66-71.

Hales T, Bertsche P [1992]. Management of upper extremity cumulative trauma disorders. American Association of Occupational Health Nursing Journal *40*(3):118-128. (A copy of this article is in Part I, pages 119-129.)

Harter B [1989]. Indications for surgery in work-related compression neuropathies of the upper extremity. Occupational Medicine: State of the Art Reviews *4*(3):485-495.

Hopkins A [1990]. The social recognition of repetition strain injuries: an Australian/American comparison. Social Sciences & Medicine *30*(3):365-372.

Hudock S, Keran C [1992]. U.S. Bureau of Mines Information Circular No. 9319: Risk profile of cumulative trauma disorders of the arm and hand in the U.S. mining industry. Minneapolis, MN:Twin Cities Research Center, U.S. Bureau of Mines, 8 pp.

Hybbinette C, Mannerfelt L [1975]. The carpal tunnel syndrome. A retrospective study of 400 operated patients. Acta Orthopaedic Scandinavica *46*(4):610-620.

Hymovich L, Lindholm M [1965]. Hand, wrist, and forearm injuries. The result of repetitive motions. Journal of Occupational Medicine *8*(11):573-577.

Joseph B [1989]. Ergonomic considerations and job design in upper extremity disorders. Occupational Medicine: State of the Art Reviews *4*(3):547-557.

Katz J, Larson M, Fossel A, Liane M [1991]. Validation of a surveillance case definition of carpal tunnel syndrome. American Journal of Public Health *81*(2):189-193.

Katz J, Larson M, Sabra A, Krarup C, Stirrat C, Sethi R, Eaton H, Fossel A, Liang M [1990]. The carpal tunnel syndrome: diagnostic utility of the history and physical examination findings. Annals of Internal Medicine *112*(5):321-327.

Keyserling W, Stetson D, Silverstein B, Brouwer M [1993]. A checklist for evaluating ergonomic risk factors associated with upper extremity cumulative trauma disorders. Ergonomics *36*(7):807-831.

Kilbom A [1988]. Intervention programmes for work-related neck and upper limb disorders; strategies and evaluation. Ergonomics *31*(5):735-747.

Kroemer K [1992]. Avoiding cumulative trauma disorders in shops and offices. American Industrial Hygiene Association Journal *53*(9):596-604.

Kulick M, Gordillo G, Javidi T, Kilgore E, Newmeyer W [1986]. Long-term analysis of patients having surgical treatment for carpal tunnel syndrome. Journal of Hand Surgery *11A*(1):59-667.

Lanz U [1977]. Anatomical variations of the median nerve in the carpal tunnel. The Journal of Hand Surgery *2*(1):44-53.

Laubli T [1987]. Preferred settings in VDT work: the Zurich experience. In: Knave B, Wideback P, eds. Work with Display Units 86, International Scientific Conference on Work with Display Units, Stockholm, Sweden. New York, NY:Elsevier Science Publishers, pp. 249-262.

Louis D [1987]. Cumulative trauma disorders. The Journal of Hand Surgery *12A*(5)Part 2:823-825.

Lubbers L, Wilson C, Gordon C [1992]. Cumulative trauma disorders of the upper extremity. Physical Medicine and Rehabilitation: State of the Art Reviews *6*(2):233-244.

Lynch R, Rodriquez A [1992]. Carpal tunnel syndrome: considerations for rehabilitation. Journal of Applied Rehabilitation Counseling *23*(3):23-29

Masear V, Hayes J, Hyde A [1986]. An industrial cause of carpal tunnel syndrome. The Journal of Hand Surgery *11A*(2):222-227.

McDermott F [1986]. Repetition strain injury: a review of current understanding. The Medical Journal of Australia *144*(4):196-200.

Moore A, Wells R, Ranney D [1991]. Quantifying exposure in occupational manual tasks with cumulative trauma disorder potential. Ergonomics *34*(12):1433-1453.

Pfeffer G, Gelberman R, Boyes J, Rydevic B [1988]. The history of carpal tunnel syndrome. The Journal of Hand Surgery *13B*(1):28-34.

Phalen G [1972]. The carpal tunnel syndrome: clinical evaluations of 598 hands. Clinical Orthopaedics and Related Research *83*(March-April):29-40.

Phalen G [1966]. The carpal tunnel syndrome: seventeen years' experience in diagnosis and treatment of six hundred fifty-four hands. Journal of Bone and Joint Surgery *48A*(2):211-228.

Phalen G, Kendrick J [1957]. Compression neuropathy of the median nerve in the carpal tunnel. Journal of the American Medical Association *164*(5):524-430.

Phillips R [1967]. Carpal tunnel syndrome as a manifestation of systemic disease. Annals of the Rheumatic Diseases *26*(1):59-63.

Rempel D, Harrison S, Barnhart S [1992]. Work-related cumulative trauma disorders of the upper extremity. Journal of the American Medical Association *267*(6):838-842.

Rodgers S [1987]. Recovery time needs for repetitive work. Seminars in Occupational Medicine *2*(1):19-24.

Rothfleisch S, Sherman D [1978]. Carpal tunnel syndrome. Biomechanical aspects of occupational occurrence and implications regarding surgical management. Orthopaedic Review *VII*(6):107-109.

Silverstein B, Fine L, Armstrong T [1986]. Hand wrist cumulative trauma disorders in industry. British Journal of Industrial Medicine *43*(11):779-784.

Skubick D, Calsby R, Donaldson S [1993]. Carpal tunnel syndrome as an expression of muscular dysfunction in the neck. Journal of Occupational Rehabilitation *3*(1):31-44.

Smith E, Sonstegard D, Anderson W [1977]. Carpal tunnel syndrome: contribution of flexor tendons. Archives of Physical Medicine and Rehabilitation *58*(9):379-385.

Spinner R, Bachman J, Amadio P [1989]. The many faces of carpal tunnel syndrome. Mayo Clinic Proceedings *64*(7):829-836.

Stock S [1990]. Workplace ergonomic factors and the development of musculoskeletal disorders of the neck and upper limbs: a meta-analysis. American Journal of Industrial Medicine *19*(1):87-107.

Stone W [1986]. Occupational overuse syndrome in other countries. Journal of Occupational Health and Safety *3*(4):397-404.

Thorson E, Szabo R [1989]. Tendinitis of the wrist and elbow. Occupational Medicine: State of the Art Reviews *4*(3):419-431.

United States Congress, Office of Technology Assessment [1985]. Ergonomics and prevention of musculoskeletal injuries. In: Preventing Illness and Injury in the Workplace. OTA-H-256, Washington, DC, pp. 127-135.
(A copy of this reference is in Part I, pages 131-142.)

Webster B, Snook S [1994]. The cost of compensable upper extremity cumulative trauma disorders. Journal of Occupational Medicine *36*(7):713-717.

Wieslander G, Norback D, Gothe C, Juhlin L [1989]. Carpal tunnel syndrome (CTS) and exposure to vibration, repetitive wrist movements, and heavy manual work: a case-referent study. British Journal of Industrial Medicine *46*(1):43-47.

Young V, Nemecek J, Higgs P, Ball D [1992]. Cumulative trauma disorders: an overview of the problem. Journal of Occupational Rehabilitation *2*(3):139-156.

Yu G [1992]. Preoperative factors and treatment outcome following carpal tunnel release. The Journal of Hand Surgery *17*(6):646-650.

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