

CURRENT AND FUTURE AREAS OF ERGONOMICS RESEARCH  
AT NIOSH

Vern Putz-Anderson  
Roger Jensen\*

\*Division of Safety Research  
Morgantown, West Virginia

To be presented at the 1982 Fall Industrial  
Engineering Conference  
Cincinnati, Ohio

U. S. Department of Health and Human Services  
Centers for Disease Control  
National Institute for Occupational Safety and Health  
Division of Biomedical and Behavioral Science  
Cincinnati, Ohio  
September 1982

ABSTRACT

An overview of ergonomics research at NIOSH is presented. Aspects of the following points are discussed: (1) ergonomics as a methodology for the science of work and its role within NIOSH, (2) ergonomic research at NIOSH during the 70's: foundations of the present program, (3) organizational and programmatic developments that have shaped ergonomics research at NIOSH in the 80's, (4) the expanded role of ergonomics in the prevention and control of chronic trauma disorders, (5) a survey of some ongoing ergonomic research at NIOSH and examples of new investigations of ergonomic problems.

Ergonomics research represents a small, but growing component in NIOSH's current program. The present status and recent growth of NIOSH's ergonomic program is attributed to a combination of continuing organizational and programmatic developments, which will be examined. Before I proceed, it would be well to review what is meant by the term "ergonomics" and how it is viewed as a program area within NIOSH. This background information should provide a framework for understanding the type of research activities carried out during the 70's as well as provide some rationale for the present and future role of ergonomics research at NIOSH.

1. NIOSH and Ergonomics: Scope/Definitions

Review Concepts:

- (1) Ergonomics may be defined as an applied science concerned with the design of workplaces, tools, and tasks to match the physiological, anatomical, and psychological characteristics of the worker.
- (2) Ergonomics as a discipline is multidisciplinary in that it draws heavily from the fields of physiology, anatomy, psychology and engineering for content and methodology.
- (3) Ergonomics seeks to achieve an optimal balance between the capabilities and limitations of individuals and the

associated demands of the work. Moreover, a positive by-product of achieving this balance or fit is often an improvement in the health and safety of the worker(s).

Hence, the central role of ergonomic activity in NIOSH's research plan is understandable when it is realized that the goals of NIOSH, i.e., an improvement in the health and safety of the workforce are often achieved through the application of findings from ergonomic investigations.

At NIOSH the label "ergonomics" is usually reserved for those occupational research problems where the "human factors" have been identified as key determinants affecting workplace safety and health. Moreover, as the term "human factors" suggests, the concern is with those human capacities and response patterns that are used to perform work. Hence, at NIOSH a workplace problem is categorized as ergonomic when two conditions are met: (1) there is a suspected or identified health impairment/injury that is associated with some aspect of job function and (2) the impairment/injury usually involves some aspect of the neuromusculoskeletal system. This latter condition is used to distinguish ergonomic problems from the more traditional occupational health activities for which NIOSH is well known. Examples of the latter programs include research to identify and evaluate respiratory disorders, cancer and reproductive disorders owing to workplace exposure to air contaminants. disorders are

usually included within a program of toxicology or respiratory research, where the worker is viewed primarily as a "passive target" for a disease.

There is developing, however, a gradual recognition among occupational health researchers that there are ergonomic issues associated with the prevention of cancer, lung and reproductive disorders. Some evidence in support of this position was provided a few years ago by a NIOSH-sponsored study concerned with changing existing work practices associated with the application of styrene [1]. Behavioral modification techniques were used to train workers to use safe and healthful work practices, based on simple ergonomic procedures for handling and applying toxic materials - styrene. In this study the workers were not treated as passive "targets" for styrene vapors, but were trained to protect themselves. The protection came from the application of behavioral principles to affect work practices including: (1) the safe and efficient use of work stations and walkways, (2) the correct use of spray application tools and (3) the use of effective shields, ventilation and protective clothing.

The study is important because it demonstrated that employee work patterns can be changed by the use of behavioral principles, which have the potential of reducing the risk from exposure to toxic chemicals. From an ergonomic view, significant progress was made at this worksite towards the achievement of an optimum and healthful fit of workers with their jobs.

## 2. Overview of NIOSH's Ergonomic Research During The 70's

Ergonomic research has been a part of NIOSH's program from its beginning. Many of you are familiar with NIOSH's research on heat stress, noise and vibration. The results of these studies, which were completed during the 1970's, have been reported in the open literature, and others have been widely distributed in the form of NIOSH technical reports and conference proceedings, (e.g., Assessment of Deep Body Temperatures of Workers in Hot Jobs [2], Whole-body Vibration Exposure of Workers During Heavy Equipment Operation [3], Relationships Between Several Prominent Heat Stress Indices [4], Effects of Noise on Non-Auditory Sensory Functions and Performance [5], Occupational Noise and Hearing [6].

In addition to these studies, a major concern of NIOSH's early ergonomic research program was aimed at reducing work-related injuries and disorders of the back. As a result, there has been a continuing emphasis at NIOSH on research concerned with manual materials handling and the effects of over-exertion, which is the principal cause of occupationally-induced low back pain. The results of this work, much of it performed in the mid 70's, culminated in the 1981 publication of the NIOSH Work Practices Guide for Manual Materials Handling (WPG) [7]. Many of the

findings and recommendations from the WPG were presented to this group at the last meeting of the AIE by the project officer, Dr. Donald Badger.

I do not want to repeat information presented by Dr. Badger, but I would like to use the WPG as an example of the multi-disciplinary approaches that can be used to analyze an ergonomic hazard such as manual materials handling (MMH): Basically, four distinct sets of methods were used to generate the recommendations on lifting contained in the WPG.

The first set of studies used methods from occupational biomechanics to develop models for establishing "stability envelopes." The biomechanical model served to assist in defining limits of postural extremes when handling loads in various body positions. Biomechanical modeling was also used to predict the compressibility and elasticity limits of spinal discs. Much of this biomechanical research was conducted by the Department of Industrial and Operations Engineering at the University of Michigan.

A second set of studies used a physiological approach to investigate lifting. Studies in this category consisted of measures of aerobic capacity, oxygen consumption, heart rate, and electromyography. The purpose here was to assess the cardiovascular and muscular strength demands of various lifting tasks.

A third approach to the assessment of lifting capacity involved the use of techniques from the field of psychophysics. Unlike the previous two methodological approaches, psychophysics has its roots in psychology and has only recently been adapted for use in ergonomics. The objective of the psychophysical approach was to determine if job demands were properly matched to the "subjective feelings" of fatigue of the workers. This was accomplished by determining a "threshold of fatigue" for each worker under several task constraints or loads. Much of this research was conducted by Liberty Mutual Insurance Company and by the Texas Tech Industrial Engineering Department.

The fourth set of studies used a non-experimental or epidemiology approach. Epidemiology is particularly well suited for handling the complexities of occupational health hazards. The epidemiology method stresses the need to search for multiple relationships (risk factors) between a disease and the causes. In the study of MMH, the purpose was to establish the relationship between injury rate and work load relative to workers' strength capacities. The data for the risk analysis were based on survey of 900 industrial lifting jobs and the strength measurement of the workers who performed those jobs [Preemployment Strength Testing (8)].

It should be clear from the research on lifting, that a variety of disciplines and research techniques are used to achieve NIOSH's goal, including some methodologies that are not usually associated with ergonomics research.

### 3. Organizational and Programmatic Developments In Ergonomics

The main factor which has shaped NIOSH's ergonomic program is the Institute's recent goal to "control and prevent occupational musculoskeletal disorders." Although musculoskeletal injuries/disorders account for few work-related deaths, the disorders do account for a significant amount of human suffering and loss of productivity. For example, data indicate: (a) Musculoskeletal conditions rank first among disease groups in the frequency of their effects. Nearly one-half of the nation's workforce are affected. (b) Musculoskeletal conditions represent a significant accessory factor in one-third of reported occupational injuries. (c) Cost of musculoskeletal disorders based on lost earnings and worker compensation payments exceed that of any single health disorder. Back injuries alone cost American industry an estimated one billion a year, (d) Musculoskeletal injuries, such as hernias, inflamed joints, sprains/strains account for one-third of annual compensation claims. The latter category is the most prevalent, with the back accounting for almost 50% of the disorders, followed by disorders of the ankle, knee and shoulder, (e) Finally, the frequency and impact of musculoskeletal conditions on the workforce is expected to increase over the next several decades as the average age of the workforce increases [9].

Within the past year NIOSH ergonomics interests have become focussed on occupationally-related, musculoskeletal disorders. A research program for reducing the prevalence of such disorders is now in progress. Its goals include: (1) the identification and recognition of musculoskeletal disorders and injuries arising from excessive biomechanical-demands posed by modern work methods, (2) the evaluation of work tasks/equipment/operations that contribute to such health and safety risks, (3) the development and testing of effective intervention strategies for reducing these types of hazards, including design changes in work methods and tools and (4) the development of effective dissemination procedures for reaching practitioner/user groups.

At NIOSH, program coordination for ergonomic research is a function of the "Ergonomics Working Group," organized in early 1981. At present, this group is composed of members from the Division of Safety Research and the Division of Biomedical and Behavioral Science. Interaction, however, may take place, if needed, with representatives from other NIOSH groups, such as the Divisions of Physical Sciences and Engineering, and the Division of Surveillance, Hazard Evaluation, and Field Studies. As a result of the interdivisional participation, a variety of scientific disciplines are represented in the Working Group, including: physiologists, epidemiologists, industrial engineers, physical therapists and psychologists. The unifying philosophy,

however, is the recognition of the need to blend the skills of the biological and engineering disciplines to respond to the safety and health challenges posed by modern work.

An example of this interaction occurred recently when NIOSH was requested by a local union to investigate the problem of knee injuries among carpet layers. Carpet layers use a "knee-kicker" when they install wall-to-wall carpeting. As a result the distal end of the femur is used as a tool to make an impact on the stretching device, often resulting in acute and chronic bursitis of the knee. NIOSH estimates that there is between 16000 to 20000 unionized floor layers and about 50000 nonunionized floor layers.

Researchers from three NIOSH Divisions, representing a range of scientific disciplines from medical to engineering, were called upon to study the problem. A number of these investigators are now collaborating to identify the risk factors associated with prepatellar bursitis and tendonitis, whereas others with an engineering orientation are developing control measures for the prevention of knee disorders associated with the installation of carpet.

#### 4. Ergonomic Studies Involving Chronic Trauma

Compared with lifting problems, far less attention has been paid, until now, to occupational risks associated with repeated or chronic microtrauma of the musculoskeletal system. The types of

disorders in this category are elusive in that they are often confused with aging. Months and years of repetitive stress from work may occur before an injury is clinically recognizable. Moreover, it has only been in the last few years that a relationship has been recognized between work-methods and the occurrence of "wear and tear" on the joints of the body. The concept of cumulative strain is central to this principle, and is defined as the progressive stiffening of the body tissues due to habitual, excessive muscular contraction.

Over the years the concept of cumulative strain has caused controversy, because the exact mechanism of damage is not known and is difficult to demonstrate. For example, workers may complain of overexertion and repetitive work, yet to the untrained observers the work task appears innocuous. Certain jobs, however, have recently been identified, such as upholstery stitching, meat cutting and electronic component assembly that involve unusual wrist positions and substantial force causing neurologic damage to the median nerve in the carpal tunnel. In the last few years, the characteristics of these high-strain jobs have been documented and appropriate interventions are now being designed.

Many of the interventions involve the redesign of common tools. Prior to implementing a change, however, an extensive work methods and task analysis is usually necessary to identify the critical parameters of the musculoskeletal problem. The actual

changes or interventions which are instituted, however, can be quite simple in concept. For example, in a poultry processing plant cases of carpal tunnel were diagnosed among workers performing a boning operation. The intervention consisted of redesigning the knives. Specifically, the blade was set at an angle to the handle such that the wrist could assume a more normal position while performing the cutting tasks; a strap was added and the handle size was increased. The traditional straight-handle knife caused repeated stressful flexions of the wrist, both being causal factors in carpal tunnel syndrome [10].

For the majority of tasks and jobs, however, the documentation concerning the causes of industrial handling strains is missing. Reports of injury and overexertion that involve high levels of repetition, and force are only occasionally noted. Indeed, some form of objective verification or quantification is also necessary to establish the presence or existence of the microtrauma at the worksite. Researchers at NIOSH believe that the prevention of cumulative injury is dependent on recognizing and evaluating the occupational risk factors associated with chronic trauma. To accomplish this, it is necessary to collect data on both the characteristics of the jobs or work tasks and the nature of the motion and force patterns that are used by the worker in accomplishing the task. As a result, NIOSH is conducting a study in conjunction with industrial engineers at the University of Michigan's, Center for Ergonomics to identify and quantify the traumatogenic risk factors for twelve different jobs/tasks that are candidates for producing disorders of the

upper extremity. The results of these investigations should be available in about 18 months.

To appreciate the concern NIOSH has for the role of chronic trauma in causing cumulative injury, one only has to examine data showing the changes occurring in the type of work performed by our workforce. Specifically, our society is experiencing a technological shift from heavy, physical type industry labor to a service/information type of work situation [11]. In this context, task demands can be more repetitive, prolonged, though individually not that strenuous. Moreover, these industries are populated by equal number of men and women who on the average are older than similar work groups a few generations ago. The extent of this shift is significant when one realizes that McDonalds' hamburger chain has more employees than U. S. Steel. "Golden arches not blast furnaces symbolize the current economy" (Newsweek, Feb. 16, 1981).

In 1981 NIOSH recognized this industrial trend away from heavy industry to service industries and responded by establishing a special "Chronic Trauma Initiative" for the investigation and prevention of "cumulative injury". A group of experts from industry and academia reviewed the Initiative and concluded that a clear need existed for practical research and methods for detecting and treating cumulative injury. As a result, NIOSH's ergonomic program has expanded to encompass the problems associated with "labor intensive-service industries" and the

introduction of complex mechanization and automation in industry. Examples of such research will be described next.

5. Survey of Current and Proposed Ergonomic Research

(a) Disorders Involving Routine/Repetitious Work

As indicated, the process of modernization has reduced the amount of heavy physical effort required of the worker, but in many cases has increased the amount and number of simple repetitive tasks. This trend is believed responsible for the increase in the number of cervicobrachial disorders and reports of chronic fatigue associated with the neck, shoulder and arms. Indications of the problem are now appearing among typists, telephone operators, cash register operators, retail clerks, and ticket agents.

All of these occupations are characterized by repetitive upper limb motions combined with static load and high volume work pace. In large supermarkets, for example, a worker may operate a cash register for 6 hr a day serving about 300 to 500 customers and pressing keys about 4000 to 6000 times a day. Repeated muscle activity of the fingers, hands, and arms are required not only for the operation of the keyboard, but also for moving and packing the articles. In many of these activities, continuous contraction of muscles of the shoulders, neck and back are demanded in order to keep the upper limbs raised. Dullness and pain in the shoulder, arm, hand and fingers especially on the

right side have been diagnosed among cash register operators. An incidence rate of 30% has been reported [12].

Suggestions for control of the reported disorders have included: worker rotation, reducing keying pressure, use of electronic probe sensors, adjustable counter heights and the use of more frequent rest pauses. Although, some of these changes have been introduced, the number of cases of cervicobrachial disorders continue to increase. NIOSH will be examining these problem in the coming year to determine the feasibility of implementing effective intervention and control programs.

(b) A Manual for Controlling Upper Extremity Disorders

The response of users to NIOSH's Work Practices Guide For Lifting has served as a stimulus for the development of a second manual. This manual will focus on problems involving the upper extremity, such as carpal tunnel syndrome, tendonitis and tenosynovitis. Moreover, many of these disorders are associated with jobs or tasks that have work patterns conducive for producing chronic trauma.

The development of the manual will be a multi-disciplinary effort involving experts in the fields of biomechanics, osteoarthritis, physical therapy, epidemiology, and industrial engineering. Its contents will address: (a) the recognition of cumulative trauma disorders (CTD) of the upper extremities, (b) job or workplace

characteristics associated with CTD and (c) programs for controlling CTD, including tool and workplace redesign. The manual will be given a trial-application by select users and evaluated for its usefulness before it is released as a NIOSH guide.

(c) Working with VDT's

One of NIOSH's more prominent projects in the area of ergonomics is the research being conducted on the health effects of working with Video Display Terminals (VDT's). This program of research has been underway for the last two years. The overall aim is to define and eventually control the potential stressors - physical and psychological - in jobs subject to technological change via use of computers and electronic displays. This research includes an ergonomic assessment of lighting, glare, noise, equipment features and anthropometric factors in the workplace. The breadth of this research is indicated by the types of response measures which are being collected. They include performance levels (rate and errors) blood pressure, heart rate, muscle tension, visual function, biomechanical analysis and a mood/physical symptom checklist. As with many of the ergonomics problems that NIOSH has been involved in, the problems were first documented in a series of worksite investigations [13]. In the case with the VDT problem, the worksite studies were conducted at three large newspaper companies that had recently introduced VDT's. Since then, NIOSH has implemented a systematic set of studies in the laboratory aimed at assessing potential high-risk

job/tasks and equipment/environmental factors. The results of a number of such studies have been completed and are scheduled to be released in the next year.

(d) Alternative Work Schedules

Recent reports have indicated that a growing tendency in industry is to adopt non-traditional work schedules, including the 4-day/40 hour compressed work week [14-16]. As of May, 1978, 1.9 million non-farm workers were engaged in such work shifts. The above reports also indicate the lack of definitive health/safety information involving these types of work hours. Of specific concern are the fatigue consequences of lengthening the individual workday, and the report of worker inability to perform certain operations. One obvious outcome of chronic fatigue is an increase in the incidence of accidents and musculoskeletal disorders.

The main purpose for studying the extended workday is to examine aspects of fatigue build-up as a function of task load for extended work periods, up to 12 hours in length. Both performance and health status of workers will be assessed before and after completing extended work schedules. Moreover, the type of work will be evaluated, in laboratory studies to determine whether it is primarily cognitive or physical. Data from this research effort will be used to define a fatigue/workload model to predict which job types/occupations would be most vulnerable to increased

overexertion and/or accident risk owing to extending the workday. A major output of this work will be a set of guidelines for fatigue allowance, given different task loads and length of workshift.

(e) Static/Constrained Postures

Fatigue also is associated with maintaining static postures, or repeatedly assuming postures which have awkward static components (e.g.,: maximum shoulder abduction, exaggerated scoliotic or lordatic spine). Such postures have been associated with overexertion injuries, particularly low back pain. Confining/constraining work postures can also contribute to musculoskeletal strains as can a stooped work position.

Postural stresses are high in the following situations:

- Bending the back either forwards or sideways.
- Holding extended arms forwards or sideways.
- Standing in one place for long periods.
- Putting body weight on one leg while the other leg operates a pedal.
- Bending head and neck forwards or backwards for long periods [17].

Postural efforts are associated with an increased risk of:

- Inflammation of the joints.
- Inflammation of the tendon-sheaths.
- Inflammation of the attachment-points of tendons.

- Symptoms of chronic degeneration of the joints in the form of chronic arthroses.
- Painful induration of the muscles.
- Disc troubles [17].

In cotton mills, for example, stooped postures were associated with sciatica (50% of cases), low back pain (80%) and degenerative spinal disc changes (85%) [18]. Many of these same workers are also required to sit or stand in one place for long hours. Body activities of workers at risk are characterized by the continuous repetition of upper limb movement with a minimum or absence of torso movement and/or constant pressure from standing. These latter factors are contributing to increased injuries of the lower extremities, which include varicose veins, foot, ankle and knee traumas. The population at risk exceeds 10 million workers engaged in jobs ranging from sedentary office work to more vigorous activity (miners, mechanics, electricians).

Identification of awkward postures at the worksite is not always obvious, and the relationship between the severity of the postures assumed and the onset of muscular fatigue remains to be clarified. A quantitative measure of the effects of posture which could alter work/rest regimens is not yet available for work situations. Moreover, information is also needed to make recommendations for job redesign where awkward static postures are likely to be present (e.g., conveyor loading, pushing or pulling stock carts, etc.) and could be avoided. NIOSH will

initiate some exploratory work in this area. A major objective is to develop guidelines for the design and layout of jobs, workplaces, machines and tools to minimize static effort due to inadequate postures.

(f) Research into Traumatic Injury

The final program of ergonomic studies that I want to draw your attention to are the investigations concerned with traumatic injury at work and means for its control. Problems identified in this area from the analysis of prevalence data indicate that the largest groups of occupational injuries are associated with falls, machine operations, and manual materials handling. Among the various approaches for reducing these injuries, the ergonomics approach has been found to be the most useful because it combines knowledge from the engineering, managerial, and behavioral sciences into one overall way of looking at each problem. For example, one important safety problem is the 2000 amputations suffered annually due to the operation of power presses. NIOSH is conducting three research projects. One is an engineering analysis to determine the reliability of presence sensing safeguarding devices such as "light-curtains" and "radio-frequency sensors." The second is a comparison of the productivity and the stress experienced by workers operating presses equipped with two different methods for actuation and protection. A third study is concerned more with the human side of the man-machine relationship. This study is to obtain data for characterizing the hand speed of press operators when

performing an after-reach motion in order to more accurately establish the distance which is needed between two-hand actuator buttons and the point of operation of the press. The approach to the press injury problem illustrates the ergonomics perspective of looking at the problem from a systems point-of-view rather than restricting the focus to a narrower disciplinary perspective such as mechanical engineering.

Ergonomic studies concerned with injuries due to falls include: (a) a study of risk factors associated with falls on stairs, (b) a study to characterize risk factors associated with pushing and pulling tasks, and (c) a recently completed study which identified factors associated with injuries resulting from slipping or tripping on working surfaces [19].

Ergonomic studies concerned with musculoskeletal injuries associated with manual materials handling include: (a) a field study to compare different methods for assessing the stresses associated with manual materials handling tasks, and (b) a laboratory study to determine the optimal design for box type containers used to manually transport materials. Both of these studies are being performed by industrial engineering departments of major universities pursuant contracts with NIOSH.

#### Summary

The current ergonomic program at NIOSH has evolved from research

projects concerned almost exclusively with physical or environmental hazards, i.e., heat, noise, moving heavy loads -to research that focuses on job demands and task/work characteristics of the service and information industries. Moreover, most of NIOSH's ergonomic research program is aimed at preventing or controlling musculoskeletal disorders, particularly those disorders that are precipitated by chronic trauma.

Interventions that have been proposed as a result of NIOSH's ergonomic studies for controlling occupational injuries/disorders have included the redesign of equipment/tools, workstations and the development of new work practices based on ergonomic principles. The results of our experience in ergonomic research over the last 12 years has reinforced the notion that research which achieves an improvement in the match between workers with their jobs is compatible with NIOSH's goal of improving the health and safety of the workforce.

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| 4. Title and Subtitle Current and Future Areas of Ergonomics Research at NIOSH                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |  |                                                                                                                  | 5. Report Date<br>82/09/00                     |                |
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| 7. Author(s) Putz-Anderson, V., and R. Jensen                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |  |                                                                                                                  | 8. Performing Organization Rept. No.           |                |
| 9. Performing Organization Name and Address Division of Biomedical and Behavioral Science, NIOSH, U.S. Department of Health and Human Services, Cincinnati, Ohio                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |                                                                                                                  | 10. Project/Task/Work Unit No.                 |                |
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| 12. Sponsoring Organization Name and Address                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |  |                                                                                                                  | 13. Type of Report & Period Covered            |                |
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| 15. Supplementary Notes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |  |                                                                                                                  |                                                |                |
| <p>16. Abstract (Limit: 200 words) A review of ergonomic research conducted by NIOSH during the 1970s was presented along with a study of the foundations of current research in this area. Also noted was the role of ergonomics as a methodology for the study of the science of work, the role of ergonomics in the prevention and control of chronic trauma disorders, and a survey of ongoing studies and new investigations. Ergonomics was viewed as an applied science concerned with the design of workplaces, tools, and tasks to match the physiological, anatomical, and psychological characteristics of the workers. Studies in the past have been concerned with the assessment of deep body temperatures of workers in hot jobs, whole body vibration effects during heavy equipment operation, relationships between heat stress indices, effects of noise on nonauditory sensory functions and performance, and the occupational noise and hearing loss relationships. Much effort has been given to work related injuries and disorders of the back resulting from ergonomic factors. Studies have investigated lifting problems, repeated or chronic microtrauma of the musculoskeletal system, the concept of cumulative strain, and the redesign of common tools. Recent studies were concerned with video display terminal usage, flexible work schedules, traumatic injury, and posture.</p> |  |                                                                                                                  |                                                |                |
| 17. Document Analysis a. Descriptors                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |  |                                                                                                                  |                                                |                |
| <p>b. Identifiers/Open-Ended Terms NIOSH-Publication, NIOSH-Author, Biomechanics, Back-injuries, Human-factors-engineering, Task-performance, Job-stress, Worker-health, Mental-stress, Hot-environments, Work-environment, Industrial-noise, Musculoskeletal-system-disorders, Hand-tools, Safety-engineering</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |  |                                                                                                                  |                                                |                |
| c. COSATI Field/Group                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |  |                                                                                                                  |                                                |                |
| 18. Availability Statement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |  | REPRODUCED BY<br>U.S. DEPARTMENT OF COMMERCE<br>NATIONAL TECHNICAL INFORMATION SERVICE<br>SPRINGFIELD, VA. 22161 |                                                |                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  | 19. Security Class (This Report)                                                                                 | 21. No. of Pages<br>27                         |                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  | 22. Security Class (This Page)                                                                                   | 22. Price                                      |                |