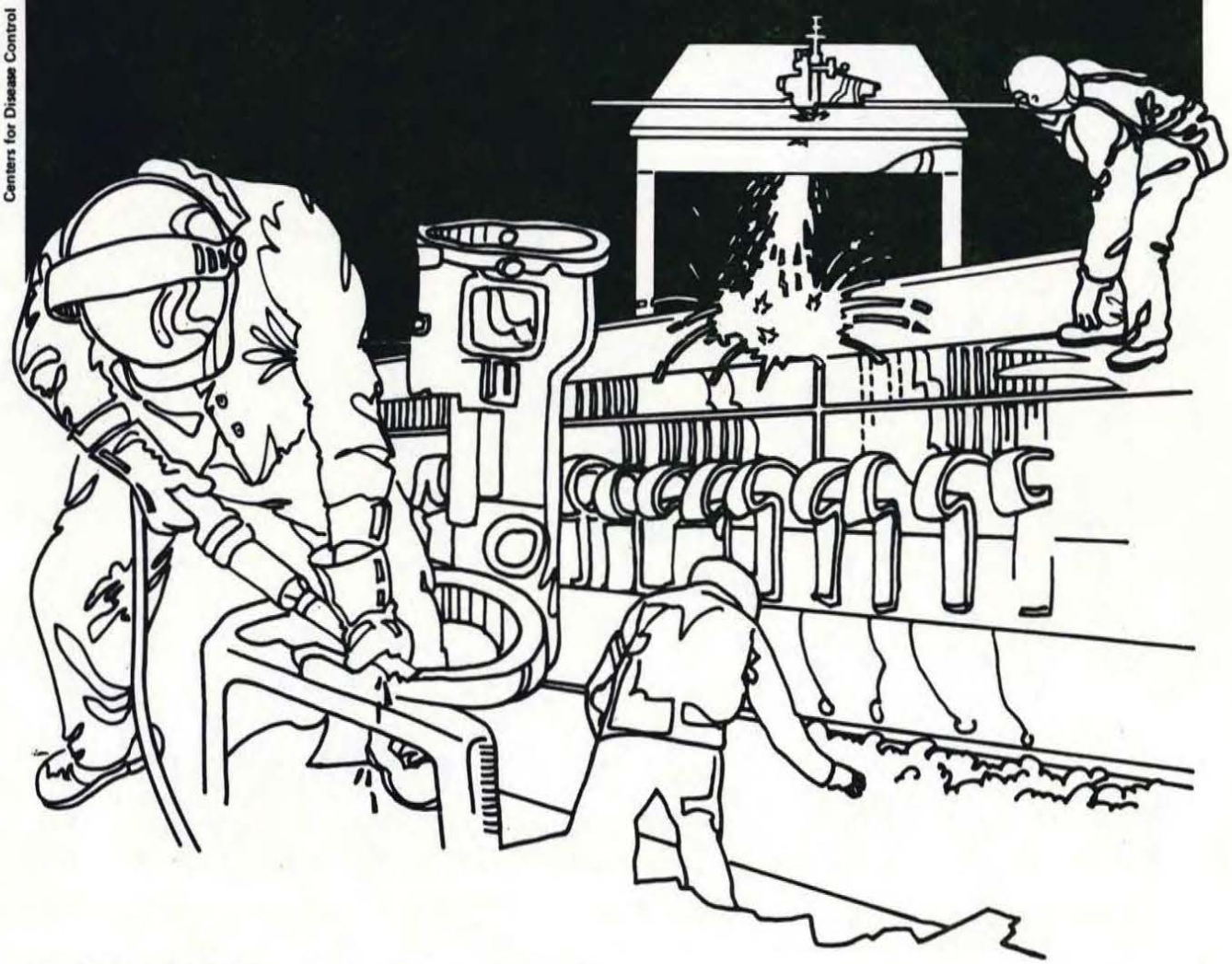
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health

NIOSH



Health Hazard Evaluation Report

HETA 84-240-1902
WESTERN PUBLISHING CO.
RACINE, WISCONSIN

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

HETA 84-240-1902
JUNE 1988
WESTERN PUBLISHING CO.
RACINE, WISCONSIN

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I. SUMMARY

In March 1984, the National Institute for Occupational Safety and Health (NIOSH) received a request from the management of Western Publishing Company, Inc., in Racine, Wisconsin, to evaluate the occurrence of carpal tunnel syndrome (CTS) among employees of the book manufacturing plant. Of 665 hourly employees, 519 (78%) completed an initial survey questionnaire in July 1984 to determine the prevalence of musculoskeletal symptoms. Forty-eight workers were thus identified as possible cases of CTS. In a subsequent study performed in December 1984, 11 of the 48 were diagnosed as probable CTS, from questionnaire responses and clinical evaluation. These eleven were compared with 22 persons who had no musculoskeletal symptoms in regard to ergonomic stress levels, as measured by analysis of videotaped job performance. For all four body areas assessed, the cases had higher stress scores than the non-cases, though the differences were not statistically significant at the 0.05 level.

Review of OSHA 200 Logs of work-related injuries and illnesses maintained by the plant, identified 25 cases of "disorders associated with repeated trauma" during the six-year period from 1979 through 1984. The highest rate of such disorders, which includes CTS, occurred in the cylinder press department. This area is recognized by plant personnel as particularly stressful, in terms of the repetitive work, excessive force, awkward postures, and handling of vibrating tools used in the stripping process. Also elevated were the rates of cumulative trauma disorders and CTS among bindery workers, compared with other non-bindery hourly workers. Comparison of the plant-wide rate of disorders associated with repeated trauma with the rate published by the Bureau of Labor Statistics (BLS) for other book printing and publishing facilities (SIC 2730) shows that Western Publishing Company's rate is more than seven times the rate of other plants performing similar operations.

The results of this evaluation demonstrate that there is an association between work-related stresses and the development of carpal tunnel syndrome and other cumulative trauma disorders at Western Publishing. From the OSHA Logs maintained by the company, the departments at highest risk for these musculoskeletal problems are the cylinder press and bindery operations. Ergonomic assessment of various jobs and work practices has identified several factors that may contribute to the rate of cumulative trauma disorders experienced by employees. These include excessive handling (jogging/fanning), poor postures resulting from inappropriate work station design, and high levels of force required by excessive weight of materials. Recommendations to control biomechanical hazards are included in Section VIII of this report.

Keywords: SIC 2732 (book printing), ergonomics, carpal tunnel syndrome, musculoskeletal injury

II. INTRODUCTION

On March, 14, 1984, NIOSH received a request from the management of the Western Publishing Company, Inc., Racine, Wisconsin to evaluate cases of carpal tunnel syndrome (CTS) thought to be secondary to repetitive motion associated with work at the book manufacturing plant.

NIOSH investigators made an initial visit on May 1, 1984, and a letter summarizing the walkthrough visit was forwarded to the company on May 25, 1984. This letter was distributed by the company to the seven unions representing workers at the plant. A review of the OSHA 200 logs revealed 15 cases of carpal tunnel syndrome recorded for the period 1979 through March, 1984, 11 of which occurred in the first floor bindery area, Departments 330 and 331. A follow-up visit was made on July 24-25, 1984, at which time a screening questionnaire was administered to current employees to determine the prevalence of wrist symptoms throughout the plant by department and job title, and to identify cases of potential CTS for a case-control study. On September 4, 1984, general and specific ergonomic recommendations were forwarded to the company based on the July visit. On November 9, 1984, a letter with accompanying tables describing the results of the screening questionnaire was sent.

On December 3-5, 1984, a subsequent medical and ergonomic study was conducted with 84 employees participating. On April 8, 1985, a letter describing delays related to data preparation was sent to the company. On March 21, 1986, the results and recommendations of the ergonomic evaluation based on an analysis of the videotapes, along with copies of the videotapes, were sent to the management. This letter included a breakdown by department of the observations and recommendations.

III. BACKGROUND

The Racine facility of Western Publishing was constructed in 1929. At the time of the initial survey, there were approximately 815 employees, 665 hourly and 150 salaried. The company prints, binds, and packages books, along with a wide range of other printed materials, including pamphlets, coupons, and playing cards. The areas of concern were the main plant (#2) and plant "6", which were exclusively devoted to printing operations and related activities. In the main plant, there were two binderys, a folding department, a cylinder stripping area, and a flat cutting operation. In plant 6, there were two binderys. Both plants operated six days per week over three shifts. Approximately 40% of the workforce in the production area was female. No information was available regarding the racial composition of the workforce.

The bookbinding operations require considerable manual material handling. In pocket feeding areas, where signatures are unloaded and fed into machines, each stack of signatures requires varying degrees of bending and

jogging in order to maintain quality control and production standards. In addition to the potential ergonomic hazards posed by material handling, a wide variety of lifting operations are performed in moving materials from pallets to machines. Other than the physical agents, a wide variety of water-based lacquers, adhesives, and degreasing agents are used in the printing and binding operations. Exposures to these chemicals were not addressed in this hazard evaluation.

IV. EVALUATION DESIGN AND METHODS

On July 24-25, 1984, a brief questionnaire was administered to 519 of 665 (78%) current hourly employees. The questionnaire elicited basic demographic information, job information, information about the presence and severity during the past month of selected upper extremity symptoms, and a brief medical history. Those people who reported "repeated feelings of numbness, tingling, or pins and needles sensation in one or both hands" and who reported that "any of the above-named symptoms ... caused you to be awakened while sleeping" were considered to have symptoms compatible with (but not proof of) carpal tunnel syndrome (CTS).

All 48 people with that symptom pattern were selected for the follow-up study. In addition, 34 individuals who reported no upper extremity symptoms were randomly selected as a comparison group. (Two additional individuals requested to participate in the follow-up survey. Although they were examined, their results are not included in the analyses.)

The follow-up study, performed on December 3-5, 1984, included the following:

1) Completion of an in-depth self-administered questionnaire. Information elicited included: demographics; a work history; detailed medical history of relevant injuries and illnesses; symptomats involving the fingers, hands, wrists, arms, elbows, shoulders, and neck, including severity and time of onset.

2) A physician's examination of both upper extremities, with attention to the hands and wrists. The physician was not aware of the symptom status of the study participants. His examination focused on physical findings related to a variety of musculoskeletal conditions of the joints, muscles, and nerves of the arms. A description of the physical examination procedures and diagnostic criteria are listed in Appendix 1.

3) Anthropomorphic measurements (body height and weight; wrist circumference, depth, and width)

4) Measurement of grip strength in both hands using a Smedley hand dynamometer.

5) Determination of vibration threshold for the second and fifth digits of both hands using an Optacon.[1] The vibration threshold was determined using the forced choice method of test administration, performed with head phones providing white noise in both ears to render the sound of the Optacon inaudible. The hands of the operator were not visible to the participant during the test administration.

6) A videotape recording was made of each participant, focusing on hand and wrist movements. Analysis was performed by an ergonomist, unaware of the worker's status as a case or control. The analysis scheme used resulted in ergonomic stress indices, measuring forces on the back, neck, shoulders, hands, and total postural load of each worker evaluated (Appendix 2). The stress score for the hands was used as the primary measure of ergonomic stress in the epidemiologic analyses presented in this report.

For purposes of analyses presented in this report, a person is considered to be a "case" of carpal tunnel syndrome (CTS) if she/he reported a pattern of symptoms consistent with CTS on both the screening questionnaire (July 1984) and the follow-up questionnaire (December 1984). In addition, the clinical evaluation performed in December 1984 must have resulted in a diagnosis of definite or possible CTS. Conversely, a "non-case" is considered to be a person who had no musculoskeletal symptoms (including hands, forearms, elbows, and shoulders) on either questionnaire and did not have a diagnosis of CTS by physical examination. (Individuals with a diagnosis of ulnar nerve compression were also excluded from being a "non-case.")

For some analyses, departments were classified as "low stress" and "high stress" in terms of ergonomic stress on the hands. Lower stress jobs had scores below the mean score for all jobs, while higher stress jobs were equal to or above the mean score. This categorization was made using the stress score, described in Appendix 2. Table 1 presents the departments by stress level. (Three departments, each represented by one worker in the study population, are not included in this classification, as videotape analysis was not performed.)

OSHA 200 Logs maintained by the company were reviewed for the six-year period from 1979 through 1984. From these logs were abstracted any disorders considered to be associated with cumulative or repeated trauma. In order to calculate a rate of cumulative trauma disorders (CTD) among workers at Western Publishing, the number of workers employed at the plant in 1984 was multiplied by 6 (years), and further multiplied by 2000 (40 hours per week times 50 weeks per year). This resulted in an estimate of the number of person-hours worked at the plant between 1979 and 1984. The resulting rate of CTDs was compared with the rate of "disorders associated with repeated trauma" from the Bureau of Labor Statistics (BLS) Annual Report of Illnesses and Injuries,[2] as listed for the Standard Industrial Classification (SIC) 2730, which includes book printing and publishing companies in the United States.

V. EVALUATION CRITERIA

Cumulative trauma disorders (CTDs) of the musculoskeletal system often occur in workers with jobs that require repetitive upper extremity exertion. These disorders can present themselves as bursitis, ganglionic cysts, musculoskeletal strain, synovitis, tendinitis, tenosynovitis, and/or numerous other specifically described musculoskeletal syndromes, including carpal tunnel syndrome. Studies have shown that these disorders can be precipitated and aggravated by activities associated with repetitive exertion, particularly if completion of the tasks requires significant application of force in an awkward posture.[3-16] The postures most often associated with upper extremity CTDs are wrist extension and flexion, ulnar and radial deviation of the wrist, open-hand pinching, twisting movements of the wrist and elbow, and shoulder abduction. CTDs are considered in many cases to be work-related because these types of postures and movements are required in many manufacturing and assembly jobs in industry. Occupations for which a high incidence of CTDs are known to exist include electronic components assembly, textile manufacture, small appliance manufacturing and assembling, meat processing and packing, fish filleting, buffing, and filing. The incidence of CTDs in these and other industries has not yet been established, but incidences as high as 44 cases per 100 workers per year have been reported.[17] Non-occupational risk factors for CTDs include: hobbies and recreational activities, such as woodworking, tennis, weight lifting, knitting, and sewing. All of these pastimes impose physical demands on the musculotendinous system similar to those of the jobs mentioned above.

Carpal tunnel syndrome was recognized as a clinical entity as early as 1895. However, not until 1947 was this median nerve problem fully described and recognized as a syndrome in medical literature. The presently accepted clinical presentation of the syndrome includes: pain and parasthesias (burning and tingling sensation) in the hand along the distribution of the affected median nerve, precipitation of similar symptoms at night while sleeping, and possible radiation of pain to other portions of the involved arm/hand.[18-22] Carpal tunnel syndrome may be associated with non-occupational factors such as acute trauma, diabetes mellitus, hormonal factors (use of oral contraceptives, pregnancy, gynecological surgery), rheumatoid arthritis, acromegaly, wrist shape/size, congenital (at birth) defects, and gout.[23] Since a number of these conditions are unique to women, their risk of carpal tunnel syndrome may be elevated. While women have been reported to be at high risk for CTS due to occupational factors, very few studies have compared the rate of CTS in men and women performing identical jobs. Silverstein, et al. found that women and men were at essentially the same risk if performing identical job activities.[24,25]

There are several factors which may precipitate occupational cumulative trauma injury. Among these are excessive muscular force, short length of job cycles, and high frequency of movements. One study found that workers

performing jobs with force levels of 4 kilograms or more were four times as likely to develop a hand/wrist CTD than those workers whose jobs required muscular exertions of 1 kilogram or less.[26] Job tasks with cycle times lasting 30 seconds or less were found to be associated with an incidence of upper extremity CTDs three times greater than those jobs where the cycle time was greater than 30 seconds.[26] In studies reporting an increased incidence of CTDs, where the number of hand movements were recorded, the range was from 5000 to 50,000 repetitions per day.[27-33] The work activities were varied and included cutting poultry, keystroking, hand sanding/filing, and packing tea.

Because of the complexity of repetitive motion patterns, it has been difficult to define a critical frequency factor for defining a CTD risk. Therefore, the current strategy for reducing the risk of CTDs for a certain task is to minimize exposure to job factors that are biomechanically stressful, i.e., involve high force, awkward postures, or high repetition rates. Reduction in risk for precipitation of CTDs and other musculoskeletal injuries is most effectively achieved through the redesign of work stations, tools, and/or reassessment of work methods.

VI. RESULTS

Of the 519 individuals who participated in the initial screening survey in July 1984, 48 (9.2%) were considered potential cases of carpal tunnel syndrome (CTS), based on a history of feelings of numbness, tingling, and pins and needles sensations in one or both hands, which caused the individual to be awakened while sleeping. Subsequent to the follow-up survey in December 1984, of these 48, only 11 (23%) were considered to have CTS, based on a more restrictive definition, i.e., a "case" based on both initial and follow-up questionnaires and physical examination findings. A similarly restrictive definition of a "non-case" (no symptoms or signs compatible with CTS on either questionnaire or on examination) yielded 22 individuals classified as "non-cases." The remaining 59 individuals had some upper limb symptoms or abnormalities on examination, but are not considered as cases of CTS in the analyses presented in this report.

Information regarding demographics and anthropomorphic measurements is presented in Table 2. The cases are older than the non-cases (mean age: 48.5 vs. 40.0; $p=0.04$). In addition, they are slightly shorter (mean height (inches): 64.3 vs. 66.5; $p=0.03$); however, the difference is less significant when the data are stratified by gender. There is a higher percentage of women among the cases than the non-cases (82% vs. 67%), though the difference is not statistically significant.

The ergonomic stress scores of the hands, shoulders, neck, back, and total postural load are provided in Table 3. The mean scores of the cases are higher than those of the non-cases for each of the indices, but none of the differences was statistically significant at the 0.05 level.

In order to investigate the possible effect of hormonal factors on the development of CTS in this population, three parameters were assessed among the women in the study. The odds of having had a hysterectomy, ever using oral contraceptives, and the number of pregnancies experienced were compared between cases and non-cases. The number of women in these analyses was relatively small; however, no association was seen between any of these potential risk factors and CTS (Table 4).

The Optacon was used as a screening device for peripheral neuropathy that results in decreased threshold of vibration sensation. This tool has been shown to be useful in identifying individuals with loss of finger sensitivity due to conditions such as carpal tunnel syndrome. The performance of workers classified as "cases" of CTS was compared with that of "non-cases." In this analysis, a logarithmic transformation of the thresholds was performed to improve the normality of the distribution of the results. The results presented in Table 5, however, have been reconverted to the arithmetic scale. Analysis of covariance was used to adjust mean threshold scores for age and gender. Although in most cases the thresholds of the cases were slightly lower than the non-cases, none of these differences was significant (Table 5). These results do not support the hypothesis that there is a sensory nerve dysfunction.

Grip strength of both hands was measured and found to be lowered in the cases than in the non-cases. These differences existed even when controlling for the effects of age and sex. On the average, the cases were able to grip 2.8 pounds less than the non-cases with their right hand ($p=.32$) and 4.5 pounds less with their left hand ($p=.03$) (Table 5). This finding is consistent with the effects of cumulative trauma disorders, including carpal tunnel syndrome.

As an attempt to identify departments or job processes that might be at elevated risk of resulting in cumulative trauma disorders, the prevalences of CTS were estimated and compared between high and low stress departments (based on ergonomic analysis of videotapes). The number of workers employed in each department was obtained from company records. However, for several departments, this number was not available and had to be estimated. For that reason, rates for individual departments could not in all cases be calculated with confidence. Therefore, only overall rates for high and low stress departments are presented (Table 6). There was a relatively small number of cases of CTS, as defined by the most restrictive criteria, distributed throughout the plant. However, the case definition of possible CTS derived from the initial screening questionnaire identified 32 individuals in the high stress departments and 14 in the low stress departments. However, because almost twice as many individuals were employed in the departments considered to involve high levels of ergonomic stress, there was no difference in the overall prevalence rates of CTS (high vs. low: 7.3/100 vs. 6.6/100 workers).

Review of the OSHA 200 Logs for the years 1979 through 1984 revealed 25 conditions associated with cumulative or repeated trauma (Table 7). These included 15 cases of carpal tunnel syndrome, 2 cases of trigger thumb, 6 cases of tendinitis, 1 ganglion, and 1 case of pain and numbness in the arm. Of the 25 disorders, 19 occurred among workers employed in bindery operations. In addition, 11 of the 15 cases of CTS occurred among bindery workers. It is estimated that of the 665 hourly workers employed at Western Publishing, 303 worked in bindery operations, and 362 worked in another department. The relative risk (RR) of experiencing a cumulative trauma disorder, as recorded on the OSHA 200 Logs, was significantly elevated among bindery workers (RR=3.8; 95% Confidence Interval (CI): 1.6, 8.9). Similarly, bindery workers experienced more than three times as much carpal tunnel syndrome as non-bindery (RR=3.3; 95% CI: 1.1, 9.7) (Table 8).

One of the highest stress operations, measured both by ergonomic videotape analysis and anecdotal report, is the cylinder press. Removing persons employed in that operation from the non-bindery workers increases the relative risk of CTS among bindery workers from 3.3 to 6.2 (Table 8). Two of the CTS reports were of workers employed in the cylinder press, which, with 19 employees, is among the smallest departments in the plant. The high rate of CTS in the cylinder press (1.7/100 person-years) can be compared with the rate among other non-bindery workers (0.09 cases/100 person-years); the relative risk is 18.1 (95% CI: 4.4, 74.1). Although the cylinder press operators experienced almost three times as much CTS as the bindery workers, this difference is not statistically significant, possibly due to the relatively small numbers (RR=2.9; 95% CI: 0.7, 12.2).

The estimated incidence rate of disorders associated with repeated trauma at Western Publishing for the six-year period under study is 62.7 per 20,000,000 person-hours (ph) worked. (BLS rates are presented as disorders per 20,000,000 ph, which represents 10,000 employees working 40 hours per week, 50 weeks per year.) (This number is derived by dividing the numerator of 25 disorders by the denominator, calculated as 665 employees multiplied by 6 years under study, multiplied by 2000 person-hours per year.) The incidence rate of disorders associated with repeated trauma among workers in Standard Industrial Classification (SIC) 2730, from the BLS Annual Report, is 8.5/20,000,000 ph. The incidence rate experienced at Western Publishing is therefore 7.4 times higher than the rate at other plants performing similar work. This elevated relative risk is statistically significant (95% CI: 3.8, 14.3).

VII. DISCUSSION AND CONCLUSIONS

Of 48 persons identified in July 1984 as having symptoms consistent with carpal tunnel syndrome, 11 (9%) were diagnosed in the subsequent survey as probable cases, based on responses to both the initial survey questionnaire (July 1984) and the follow-up questionnaire (December 1984), as well as the physician's examination (December 1984). A technique was developed to analyze videotapes of job performance to assess the ergonomic stresses on the hands, shoulders, neck, back, and total postural load.

Comparison was made in regard to these stress levels between individuals identified as probable cases of CTS and those who reported no symptoms on either questionnaire or during the clinical examination. The ergonomic stress levels of persons with CTS were higher for each, but none of the differences was statistically significant at the 0.05 level.

Two quantitative measures of peripheral nerve and muscle function were used in this study. There was no significant difference with respect to threshold of vibration sensation between the cases and non-cases. However, the cases had significantly lower grip strength.

Videotape analysis showed no association between ergonomic stress level of job tasks and occurrence of CTS. However, review of OSHA 200 Logs maintained by the company demonstrated that of the 25 conditions identified during the period 1979 through 1984, 19 occurred among bindery workers. The rate of these disorders was significantly higher among bindery workers when compared with non-bindery workers (RR = 5.7), and even higher when compared with non-bindery, non-cylinder press workers (RR = 9.6). The cylinder press workers experienced the highest rate of cumulative trauma disorders, and CTS specifically (1.7 cases of CTS/100 person-years). This is not surprising in light of the excessive force, awkward postures, and handling of vibrating tools used in the stripping process in the cylinder press area.

The rate of disorders associated with repeated trauma at Western Publishing was compared with the rate reported in the Bureau of Labor Statistics for other book printing and publishing facilities (SIC 2730). The source of both rates is the OSHA 200 Log, in which is recorded work-related injuries and illnesses experienced by employees. Western's rate (62.7/20 million person-hours) is over seven times the rate experienced by other plants performing similar operations in the United States (8.5/20 million person-hours). It should be noted that OSHA Log information has been shown to underreport acute and chronic musculoskeletal injury, in part due to individual differences in interpretation of the meaning of a "recordable event" and to differences in the inclination of examining physicians to label injuries as "work-related." Several studies that compared OSHA 200 Log records of cumulative trauma disorders and plant medical records demonstrated a significant underreporting on OSHA Logs.[34-36] Though this issue is not addressed in the analysis of this plant, the possibility that cumulative traumas may go unreported in OSHA Logs should be considered.

The higher number of cumulative trauma disorders (CTDs) found in the OSHA logs than in the survey conducted in December 1984 can be explained by several factors. These include the fact that the OSHA logs included a variety of disorders, not limited to the very strict definition of carpal tunnel syndrome (CTS) used in the survey. In addition, the disorders identified by OSHA logs included all cases that were reported over a six-year period, whereas the NIOSH survey identified only individuals who were experiencing symptoms of CTS over a much shorter period of time (July to December 1984).

It is apparent from these results that there is an association between work-related stresses and the development of carpal tunnel syndrome and other cumulative trauma disorders at Western Publishing. From the OSHA Logs maintained by the company, the departments at highest risk for these musculoskeletal problems are the cylinder press and bindery operations.

VIII. RECOMMENDATIONS

After review of videotapes made of workers performing a wide variety of job tasks, a number of observations and recommendations are made to reduce postural stress. Many of these recommendations were provided previously to the management and union representing workers at Western Publishing in a letter dated March 21, 1986.

1) Adequate training should be provided to all employees regarding proper work practices. Substantial overhandling of paper (excessive fanning and jogging) was observed in many individuals. Reduction in material handling should be taught and encouraged.

2) In general, the surfaces of tables for jogging and fanning materials, should be approximately 30 inches above the surface of the floor. Footstools should be provided for employees who find this height too high, or in areas where the table height is above 30 inches.

3) Job rotation within departments should be encouraged. Assuming different jobs on a line during the day allows for the use of different hand and wrist positions, limiting the wear and tear around a joint caused by a single type of repetitive motion. Consideration should be given to the removal or modification of job classification barriers that impede effective job rotation.

4) Recommendations by Department

   a. Department 321 (cylinder press): Use of a method that allows the sheets of materials to be die cut would be preferable to manual stripping. The current use of the pneumatic cutter (air hammer) exposes the worker to excessive vibration to the wrist. This vibration could be reduced by suspending the air hammer overhead using a counterbalanced system, and providing appropriate grips on the hammer. The manual ripping and tearing following the loosening of the trim by the air hammer demands a high level of ulnar deviation. If it is not possible to devise a method for die cutting, the use of a bent pliers would reduce this stress on the wrist.

   b. Department 330 (2nd floor bindery): Overhandling of materials was noted particularly in this department. The conveyor belt onto which hard-covers are loaded should be lowered to below the shoulder height. Signature loaders were observed to be perpendicular to the table, forcing an increase in reach. Signature loaders should be angled to face the operators wherever possible. The unloading operation on some lines

exceeds the grip capacity. One operation, requiring the crimping of cardboard backs, was performed by the employee with full body weight on a maximally extended wrist. Another operation, involved the handling of large amounts of big pieces of paper. The stacks of paper were too high, with the operator reaching overhead to remove paper, and often reaching over the head to stack the material. A load leveler would be appropriate here (one worker raised the heavy covers using a fork lift).

c. Department 331 (1st floor bindery): The preferable loading of signatures, with the face of the work parallel to the workers, was used for most operations. Yet, on the same lines, top loading of signatures was used. If possible, use of this stressful angle should be eliminated. The least stressful method for performing this operation is fanning the signatures toward the body, with the weight of the signatures resting on the table.

d. Department 319 (Web offset): Use of a load leveler would eliminate the excessive amount of bending over in this job to stack materials.

e. Department 332 (Plant 6 bindery): In Plant 6, Dell paperback signatures were loaded without fanning or jogging. The minimal handling of materials was excellent. Although the boxing machines generally did not present ergonomic problems, some employees appeared to be working in cramped workspaces, being too close to the conveyors to comfortably grab materials off the line.

f. Department 333 (Flat cutting): It appeared that the most biomechanically economical motion used was to fan covers using a rolling motion. In Folding Department 35, signatures being unloaded were bent prior to loading them onto the machine that binds the signatures into stacks. This bending represents an unnecessary motion since these signatures will probably be jogged at the beginning of the next operation. The large sheets on the pneumatic jogging table appear to require a lot of handling. Given the effects of the vibration of the table, the amount of handling should be reduced.

5) A surveillance program should be maintained that will identify workers with early signs of carpal tunnel syndrome and other musculoskeletal disorders of the upper extremities so that appropriate medical treatment, including work restrictions, job rotation, physical therapy, and rest, can be provided. Such a surveillance program should not be considered a substitute for the institution of engineering and work practice changes designed to reduce ergonomic stress and resulting injury.

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Publications Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. Western Publishing Company, Inc., Racine, Wisconsin
   (copies provided for distribution to all unions representing workers at plant)
2. OSHA Region V

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1

Departments by Ergonomic Stress Levels *

Western Publishing Company
Racine, Wisconsin
HETA 84-240

Department # - Name	No. in Study Population	No. in Ergonomic Analysis	Hand Stress Score (Mean (S.D.)
High Stress (hand stress score >= 9.6 **)			
650 - Shipping/Mat. Handling	3	2	12.1 (0.8)
332 - Plant 6 Bindery	8	6	11.8 (3.2)
321 - Cylinder Press	4	3	11.2 (1.3)
333 - Flat Cutting	1	1	10.4 ---
320 - Sheet-Fed Offset	17	6	10.1 (3.9)
334 - Folding/Hand Finish	3	2	10.0 (1.2)
331 - 1st Floor Bindery	12	9	9.8 (1.1)
Low Stress (hand stress score < 9.6)			
Plant 7 - Distribution	2	2	9.0 (0.1)
326 - Rotary Bindery	2	2	9.0 (0.1)
341 - Playing Card	5	4	8.6 (1.0)
330 - 2nd Floor Bindery	14	12	8.4 (1.6)
QA - Quality Assurance	3	2	8.1 (4.0)
319 - Web Offset	4	3	6.4 (1.2)
Undetermined Stress (ergonomic analysis not performed)			
325 - Rotary Press	1	0	
370 - Ink Room	1	0	
318 - Sheeter	1	0	

* Stress level based on ergonomic stress score of hands of individuals in particular departments

** 9.6 = mean hand stress score for whole population

Table 2

Demographic and Anthropomorphic Description of Study Subjects

Western Publishing Company
Racine, Wisconsin
HETA 84-240

	Cases * (N=11)	Non-Cases ** (N=22)	Others *** (N=59)	Total (N=82)
AGE	48.5 (9.3)@	40.0 (13.0)	46.6 (11.4)	45.0 (11.9)
SCHOOL (Yrs)	12.1 (1.4)	11.5 (1.6)	11.6 (1.4)	11.6 (1.4)
% FEMALE	81.8	66.7	59.2	64.3
HEIGHT (in.)	64.3 (2.6)@@	66.5 (3.0)	66.6 (4.5)	66.3 (3.7)
WEIGHT (lb.)	166.7 (31.0)	150.9 (22.0)	173.8 (44.7)	166.7 (39.1)
WRIST MEASUREMENTS:				
Circumference-R	16.5 (1.0)	16.4 (1.1)	17.2 (1.72)	16.9 (1.5)
Circumference-L	16.2 (0.9)	16.3 (1.0)	17.1 (1.6)	16.7 (1.4)
Depth-R	3.9 (0.4)	4.0 (0.5)	4.1 (0.5)	4.1 (0.5)
Depth-L	3.9 (0.4)	3.9 (0.5)	4.1 (0.5)	4.0 (0.5)
Width-R	5.5 (0.3)	5.4 (0.5)	5.8 (0.6)	5.7 (0.5)
Width-L	5.5 (0.3)	5.4 (0.5)	5.7 (0.5)	5.6 (0.5)

* Cases = symptomatic on screening and follow-up questionnaire and clinical diagnosis of CTS

** Non-Cases = asymptomatic on screening and follow-up questionnaire and clinical diagnosis of non-CTS

*** Others = symptomatic on one or both questionnaire or clinical diagnosis of CTS, but not both

@ Comparison of cases vs. non-cases, t-test: p=.04

@@ Comparison of cases vs. non-cases, t-test: p=.03 (difference decreases when stratify by gender)

Table 3

Ergonomic Scores* of Study Subjects
(Mean (S.D.))

Western Publishing Company
Racine, Wisconsin
HETA 84-240

	Cases ** (N=8)	Non-Cases *** (N=17)	Others **** (N=30)	Total (N=55)
HANDS	10.1 (1.6)@	8.6 (2.2)	10.1 (2.6)	9.6 (2.4)
SHOULDERS	2.1 (0.4)	1.6 (1.1)	2.3 (1.3)	2.0 (1.2)
NECK	4.1 (0.2)	4.0 (1.4)	4.3 (1.0)	4.2 (1.1)
BACK	17.2 (1.9)	16.7 (2.9)	19.4 (4.2)	18.2 (3.7)
TOTAL LOAD	45.5 (2.9)	41.7 (9.9)	48.5 (11.3)	45.9 (10.4)

* See Appendix 2 for explanation of ergonomic stress indices.

** Cases = symptomatic on screening and follow-up questionnaire and clinical diagnosis of CTS

*** Non-Cases = asymptomatic on screening and follow-up questionnaire and clinical diagnosis of non-CTS

**** Others = symptomatic on one or both questionnaire or clinical diagnosis of CTS, but not all three

@ Comparison of cases vs. non-cases, t-test: p=.08

Table 4

Assessment of Association Between Hormonal Factors and CTS
Females Only

Western Publishing Company
Racine, Wisconsin
HETA 84-240

		Case	Non-Case
Ever Used Oral Contraceptives	+	4	8
	-	5	7

Odds Ratio = 0.70
p = .99

		Case	Non-Case
Hysterectomy	+	3	5
	-	5	10

Odds Ratio = 1.20
p = .99

Number of Pregnancies (Mean (S.D.)):

Cases	Non-Cases	p value (t-test)
3.8 (4.1)	2.4 (1.9)	0.37

Table 5

Results of Optacon and Grip Strength Tests
Comparison of Age- and Sex-Adjusted Means

Western Publishing Company
Racine, Wisconsin
HETA 84-240

Test Parameter	Cases (N=11)	Non-Cases (N=22)	p value **
Optacon (volts)*:			
2nd finger - R	4.46	4.55	.91
5th finger - R	4.53	4.70	.85
2nd finger - L	4.27	4.69	.60
5th finger - L	5.82	5.01	.48
Difference - R (5th minus 2nd)	0.99	0.97	.84
Difference - L (5th minus 2nd)	0.73	1.07	.11
Grip Strength (lbs.):			
Right hand	31.50	33.34	.32
Left hand	30.01	34.50	.03

* Optacon analyses used a logarithmic transformation of the data; numbers reported in this table have been re-converted to the arithmetic scale for ease of interpretation.

** p value generated by analysis of covariance, used to provide age- and sex-adjusted means

Table 6

Distribution of Cases of Carpal Tunnel Syndrome
by Department

Western Publishing Company
Racine, Wisconsin
HETA 84-240

Department # - Name		No. Employed	Cases *	Possible Cases **
High Stress				
650	- Shipping/Mat. Handling	57	0	0
332	- Plant 6 Bindery	111	1	5
321	- Cylinder Press	19	0	4
333	- Flat Cutting	44	0	0
320	- Sheet-Fed Offset	97	0	11
334	- Folding/Hand Finish	33	0	2
331	- 1st Floor Bindery	75	4	10
		436	5	32
Low Stress				
Plant 7	- Distribution	10	0	2
326	- Rotary Bindery	23	1	2
341	- Playing Card	37	1	3
330	- 2nd Floor Bindery	94	3	5
QA	- Quality Assurance	5	0	1
319	- Web Offset	41	0	0
		210	5	14
Undetermined Stress				
325	- Rotary Press	11	0	0
370	- Ink Room	39	0	1
318	- Sheeter	10	0	0
		60	0	1

* Case defined by restrictive criteria (see text). (One of 11 cases thus defined provided no information on department of employment.)

** Possible case of CTS identified from initial screening questionnaire

Table 7

Review of OSHA 200 Logs (1979 - 1984)
"Disorders Associated With Repeated Trauma"

Western Publishing Company
Racine, Wisconsin
HETA 84-240

Department	Disorder
330 - 2nd Floor Bindery	Possible CTS
	Tendinitis - R
	Tendinitis - R wrist
331 - 1st Floor Bindery	CTS - R
	CTS - Bilateral
	CTS - L
	CTS
	Possible CTS - Bil.
	Tendinitis - R wrist
	Pain/numbness - L arm
332 - Plant 6 Bindery	CTS - R
	CTS - L
	CTS - R
	CTS - Bil.
	CTS - Bil.
	Ganglion - R wrist
	Trigger thumb - L
Bindery	Tendinitis - L forearm
	Tendinitis L elbow
321 - Cylinder press	CTS - R
	CTS - R
333 - Flat cutting	CTS - L
341 - Playing Card	Trigger thumb - R
350 - Shipping/Receiving	Tendinitis - R wrist
370 - Ink room	CTS - R

Table 8

Review of OSHA 200 Logs (1979 - 1984)
Comparison of Rates of Bindery, Cylinder Press, and Other Workers

Western Publishing Company
Racine, Wisconsin
HETA 84-240

Disorders Associated With Repeated Trauma

	Bindery	Non-Bindery
Disorder	19	6
PYAR *	1818	2172

RR = 3.8
95% CI: 1.6, 8.9

Carpal Tunnel Syndrome

	Bindery	Non-Bindery
CTS	11	4
PYAR	1818	2172

RR = 3.3
95% CI: 1.1, 9.7

	Bindery	Non-Bindery, excl. CP **
CTS	11	2
PYAR	1818	2058

RR = 6.2
95% CI: 1.7, 23.2

Disorders Associated With Repeated Trauma

	Cylinder Press	Non-Bindery, excl. CP
Disorder	2	4
PYAR *	114	2058

RR = 9.0
95% CI: 2.2, 36.5

Carpal Tunnel Syndrome

	Cylinder Press	Non-Bindery, excl. CP
CTS	2	2
PYAR	114	2058

RR = 18.1
95% CI: 4.4, 74.1

* PYAR: person-years-at-risk (# workers X 6 years)
** CP: cylinder press operators

Appendix 1

PHYSICAL EXAMINATION

The purpose of the physical examination will be twofold.

The first purpose is to obtain biometric measurements of all study participants, including: height; weight; grip strength; and wrist circumference, depth, and width, for use in describing any possible association between these measurements and symptoms of wrist discomfort and diagnostic outcomes.

The second purpose is to establish a diagnostic category for each participant with symptoms and signs of hand, wrist, and/or forearm disease. These diagnostic classifications will be determined by information provided on the questionnaire by each worker and by the physical findings on examination. The combination of historical and physical exam data will be used to provide each symptomatic workers with a diagnostic category based on the attached DIAGNOSTIC CRITERIA.

In the broadest terms, conditions will be classified into neurologic, inflammatory/connective tissue, traumatic, and vascular categories.

The neurologic conditions to be assessed include:

1) Ulnar nerve compression
2) Median nerve compression (Carpal Tunnel Syndrome)
3) Radial nerve entrapment
4) Cervical root syndrome

The inflammatory/connective tissue conditions to be assessed include:

1) Tendinitis of the wrist
2) Rheumatoid arthritis of the hand and wrist
3) Degenerative or osteoarthritis of the hand
4) DeQuervan's tenosynovitis
5) Trigger finger/thumb
6) Lateral epicondylitis (tennis elbow)
7) Medial epicondylitis (golfer's elbow)
8) Olecranon bursitis
9) Pronator teres syndrome

Traumatic conditions will be assessed by history and the noting of any scars, deformities, or amputations of the hands, wrists, or forearms.

Vascular lesions will be assessed by history consistent with Raynaud' phenomenon.

DIAGNOSTIC CRITERIA

ELBOW, FOREARM

1. Lateral epicondylitis (tennis elbow)
   Hx: pain at lateral epicondyle during rest or active motion of wrist and fingers.

   PE: -pain during resisted extension of wrist with fingers flexed
   -no pain or limitation on full passive ROM
   -pain at epicondyle on palpation
   -pain on resisted radial deviation of wrist but no pain on resisted ulnar dev.

2. Medial epicondylitis (golfer°s elbow)
   Hx: pain at medial epicondyle during wrist or active motion of fingers/wrist

   PE: -no pain on passive ROM
   -pain on resisted flexion of wrist
   -pain on resisted pronation
   -pain at epicondyle at palpation

3. Olecranon Bursitis
   Hx: pain or swelling at olecranon

   PE: -pain or swelling around olecranon on palpation,
   r/o RA (palpate for nodules)
   -no significant impairment of ROM

4. Radial Nerve Entrapment
   Hx: pain or numbness in lateral aspect of forearm, may project to anatomical snuffbox or 1st carpometacarpal joint, may be referred to lateral epicondyle

   PE: -weakness of dorsiflexion of the wrist
   -elbow pain with resisted extension of middle finger with elbow extended characteristic radiating pain when palpated over site of entrapment
   -loss of sensation dorsal webspace between 1st and 2nd metacarpal..

5. Pronator teres Syndrome
   Hx: burning and pain in first 3 digits of hand and forearm

   PE: -increase pain forearm by resisted pronation with fist clenched/flexed (Mills)
   -sensory impairment of thenar eminence and entire distribution of the median nerve.
   -absense of Tinel' or Phalen' signs

IST/HANDS

1. Ulnar nerve compression
   Hx: burning and numbness in ring and little finger, clumsiness in fine movements

   PE: -r/o cervical (brachial plexus) and elbow as origin of symptoms
   -decreased pinch strength of thumb
   -resisted abduction and adduction of 4th and 5th finger, weakness
   -weakness on resisted adduction of thumb
   -decreased pinprick palmar aspect of 5th finger

2. DeQuervain's disease
   Hx: pain in anatomical snuffbox, no hx of fractures

   PE: -pain and/or swelling of the abductor pollicis longus and extensor pollicis brevis
   -r/o radial nerve entrapment
   -positive Finkelstein' test

3. RA of wrist
   Hx: swelling, stiff, warm, redness, pain more than 6 weeks, other joint involvement bilateral, hx of prominent morning stiffness more than 15 minutes

   PE: swelling and tenderness of the wrist
   pain on motion of the wrist in all directions
   possible cutaneous nodules

4. Carpal Tunnel Syndrome
   Hx: pain, tingling, numbness in medial sensory distribution
   nocturnal parasthesia-medial distribution
   improve with shaking (?)

   PE: -impaired 2 point discrimination-medial distribution
   -positive Phalens or Tinels sign
   -thenar atrophy

5. RA of hand
   Hx: history of episode of three painful limb joints
   history of swelling and/or stiffness of three limb joints
   PIPs and MPs swelling, stiff, pain, warmth for more than six weeks
   prominent morning stiffness

   PE: swelling, increased warmth, pain and limitation of ROM
   (can°t make a fist)

6. Degenerative arthrosis or osteoarthritis of hand
   Hx: stiffness, pain, bony swelling-DIP joints, maybe PIP
   no wrist involvement

   PE: no tenderness, decreased flexion, bony swelling of fingers

7. Raynaud's phenomenon
   Hx: numb, pain and blanching of fingers increases with cold, no other symptoms
   r/o TOS

8. Trigger finger/thumb
   Hx: locks in extension or flexion, requires assistance of other hand to unlock
   nodule in tendon

9. Tendinitis
   Hx: localized pain over muscle-tendon structure

   PE: pain exacerbated on active ROM, fine crepitus on passive ROM
   asymmetrical grip strength

Appendix 2

A Method to Analyze Postural Constraints in Repetitive Tasks.

Thomas Laubli, M.D.

Videotapes of several working cycles of production workers are analyzed to evaluate postural elements. The rating scale is developed in such a way to provide a quick (10min/task) and reliable measure of selected working characteristics. The form on which these are recorded is provided in the Appendix 2b. A reduced number of working characteristics was selected for analyses, based on the assumption that they are critical factors in the development of musculoskeletal disorders. Emphasis is given to the load on the upper limb, including hands. The selected working characteristics are listed below:

- Hands and forearms: Extreme wrist positions, exerted force, and twisting of the forearm are important loads. Fast and repetitive finger movements are not included, because they never occur in the analyzed jobs. The duration of the working cycle is considered as a measure for repetitive movements.

- Shoulders: Emphasis is given to the muscular strain that is needed to sustain the working position of the hands. The muscular strain is dependent on the distance from the hand to the shoulder, the elevation of arms, the lifted weight, as well as the precision of the hand movements. The duration of the working cycle is considered as a measure for repetitive movements.

- Neck: Load on the neck is considered to be primarily dependent on head position and elevation of shoulders. The head position itself is not directly observed, but workload is evaluated based on observations of bending or twisting the back and elevating the arms above the shoulders, since such postures are normally combined with inclining or turning the head. Tasks involving precision are judged to cause an increased effort to stabilize the head for eye fixation. The duration of the working cycle is considered as a measure for repetitive movements.

- Low back: Bending, twisting and lifting, as well as continuous sitting or standing are considered.

Various working characteristics have been found to be associated with postural discomfort, including high working speed, repetitive movements, constrained postures, and heavy lifting. The evaluated elements noted above have been combined in order to obtain a single measure of exposure (ergonomic stress). Little is known about the interplay of these factors and therefore constructions of indices are arbitrary. Additive models are used, giving approximately the same weight to each element. Indices are constructed for

different parts of the body. Additionally, a general index is constructed to describe a combined risk for the development of musculoskeletal disorders. Though there is no definitive evidence that such a general risk factor exists that is predictive for musculoskeletal illness, the following arguments make it reasonable to test this hypothesis:

- Specific postural constraints may be overcome by adaptations of the general posture.
- Pains in specific body parts cause subjects to save the affected limb and to use more often other parts of the body.
- All postural elements are combined by many kinds of reflexes so that changes of the muscular tone are forwarded to other parts of the body.

Included in the analysis are evaluation of several factors, including identification of a working cycle, the cycle time, and a number of postural elements. Criteria for each of these are provided below.

A. Definition of Working Cycle

Normally a working cycle consists of taking a working piece, handling and depositing. Sometimes small pieces are piled directly at the workplace and only infrequently they are deposited at a dump, or new material is stocked at the workplace only from time to time. Stocking or depositing may represent another short working cycle. Tasks that are repeated one after another six or more times are considered to be separate working cycles. If one person is engaged in more than one of such working cycles, the cycles are analyzed independently and a mean is calculated. Further elements in the working process that are repeated fewer than six times are not evaluated.

B. Definition of Cycle Time

Generally cycle time is quite constant; in such cases a representative value is taken. Sometimes working cycles are interrupted by waiting times. This waiting time is combined with the cycle time in such a way that the period over several cycles is measured and divided by the number of cycles involved. The percentage of time during that postural elements occur (see below) is related to this cycle time, including average of waiting time.

C. Quantitative Assessment of Postural Elements

Postural elements that are to be observed are selected and clearly defined (see below). The occurrence of these postural elements is recorded as percentage of the duration of a working cycle. A five-step scale is used; the levels are 0-20% (1), 21-40% (2), 41-60% (3), 61-80% (4) and 81-100% (5) of the duration of a working cycle.

The registration of postural elements is dichotomous; specified postures occur or do not. Only clear deviations from the zero-position are recorded, because only these are judged to be related to postural problems and it is easier to recognize them.

D. Definition of Postural Elements

1a. Legs: sitting
Sitting is defined as sitting on a chair or on a equivalent object. Standing using a prop is not considered as sitting.

1b. Legs: standing
Subjects are standing when they are not sitting or walking. Not moving from one place to another but changing load from one leg to the other is standing.

2a. Back: bending
Bending is noted when subjects bend the upper body in such a way that it is clear to the observer that the back is bent. This position is defined as bending more than 20 degrees.

2b. Back: twisting/twisting and bending
Twisting is noted whenever the back is clearly twisted, whether or not it is also bent.

3. Right/left elbow above shoulder
Elevated positions of the arms related to the trunk are observed. If the upper body is bent forward, the elbows may actually be below shoulders, but related to the axis of the trunk they are above the shoulder; such a position is noted as "above shoulder."

4. Right/left: horizontal distance hand-shoulder
The distance between hand and shoulder is projected on a horizontal plane. It is noted if the projected horizontal distance from the wrist to the shoulder clearly exceeds the true length of the forearm (middle of wrist-elbow).

5a. Right/left hand: lifting/force involved
Separate manipulations of each hand are recorded. This may occur when only one hand is used or when both hands are involved with independent activities. When an object is held or manipulated symmetrically by both hands, it is noted under "both hands lifting/force." Holding a tool or working piece always involves some force and is therefore included here. The sum of the time with application of force as well as of lifting or holding is noted.

5b. Right/left hand: weight/force in pounds
The force exerted or the weight lifted is estimated. If different forces or weights of similar levels occur, a time-weighted average is given. If there is a distinctive peak load, it is this measure that

is recorded. The weight or applied force is estimated even if it occurs only for a short period.

5c. Both hands: Lifting/force involved

Lifting or holding an object, as well as exerting force symmetrically by both hands are recorded.

5d. Both hands: weight/force in pounds

The weight or force is noted as is described for item 5.10/5.12.

6. Precision involved

Precision involved means handling that can only be done using eye control or involves high proprioreceptive skills.

7. Right/left forearm: twisting

Repetitive movements of the forearms involving pronation and supination are recorded. A typical example for such a condition is screwing. Constant pronation or supination is not judged to be problematical.

8a. Extreme positions of right/left hand

The occurrence of extreme positions of the wrist (ulnar deviation, radial deviation, extension, flexion) is considered. The positions of concern are those that are clearly deviated from a middle position. The sum is noted during which one or more extreme wrist position occurs. Only the position of the wrist is evaluated; fingers are not taken in consideration.

8b. Specification of extreme positions of the right/left wrist

If it is observed that extreme wrist positions occur longer than 40% of the cycle period, it is so specified for ulnar or radial deviation, as well as flexion or extension. The degree of the inclination or the time intervals are not recorded.

E. Indices Describing Postural Load

Indices for various aspects of postural load (hands, shoulders, neck, back, total) are scored by the criteria listed below. The summary score for each body part under consideration is an arithmetic total of each contributing parameter.

1. Index for right/left hand.

	Theoretical Range
Right/left hand: lifting/force involved	1 - 5*
Right/left hand: weight/force in pounds natural logarithm of number of pounds plus one	0 - 4 (0 - 55 pounds)
Both hands: lifting/force involved	1 - 5*
Both hands: weight/force in pounds half of natural logarithm of number of pounds plus one	0 - 4 (0 - 110 pounds)
Precision involved	1 - 5
Right/left forearm twisting	1 - 5
Right/left wrist: extreme positions twice the value	2 - 10
Cycle time half of negative natural logarithm of cycle time in seconds (4 = 50 min)	-4 - 0
Combined index for right/left hand	2 - 34
Combined index for hand = mean of scores of left and right hands	2 - 34

* exclusive of each other

2. Index for right/left shoulder

	Theoretical Range
Right/left elbow above shoulder	1 - 5
Right/left horizontal distance hand-shoulder	1 - 5
Right/left hand: weight/force in pounds natural logarithm of number of pounds plus one	0 - 4 (0 - 55 pounds)
Both hands: weight/force in pounds half of natural logarithm of number of pounds plus one	0 - 4 (0 - 110 pounds)
Cycle time half of negative natural logarithm of cycle time in seconds (4 = 50 min)	-4 - 0
Combined index for right/left shoulder	-2 - 18
Combined index for shoulder = mean of scores of left and right shoulders	-2 - 18

3. Index for neck

Back: bending	1 - 5*
Back: twisting/twisting and bending	1 - 5*
Right elbow above shoulder	1 - 5
Left elbow above shoulder	1 - 5
Precision involved	1 - 5
Cycle time half of negative natural logarithm of cycle time in seconds (4 = 50 min)	-4 - 0
Combined index for neck	1 - 21

* exclusive of each other

4. Index for low back

	Theoretical Range
Legs: sitting	1 - 5*
Legs: standing	1 - 5*
Back: bending twice the value	2 - 10**
Back: twisting/twisting and bending	3 - 15**
Right hand: weight/force in pounds natural logarithm of number of pounds plus one	0 - 4 (0 - 55 pounds)
Left hand: weight/force in pounds natural logarithm of number of pounds plus one	0 - 4 (0 - 55 pounds)
Both hands: weight/force in pounds half of natural logarithm of number of pounds plus one	0 - 4 (0 - 110 pounds)
Combined index for back	7 - 39

* exclusive of each other, ** exclusive of each other

5. Index for total load

Index for right hand	2 - 34
Index for left hand	2 - 34
Index for right shoulder	-2 - 18
Index for left shoulder	-2 - 18
Index for neck	1 - 21
Index for low back	7 - 39
Combined index for general postural load	8 - 164

Appendix 2b
ANALYSIS OF POSTURAL ELEMEMTS IN TYPICAL WORKING CYCLES

NAME_____I.D. __ __ __ __ __ (1-5) Film Analyzer __ (6)

TASK NO __ (7) LENGTH OF CYCLE TIME: __ __ minutes __ __ seconds (8-11)

PLANT: Western __1 Standard __2 Briggs & Stratton __ 3 Prescolite __4 (12)

	% TIME OCCURS:	0-20 (1)	21-40 (2)	41-60 (3)	61-80 (4)	81-100 (5)	
1.	LEGS: sitting	1	2	3	4	5	(13)
	standing	1	2	3	4	5	(14)
2.	BACK: bending	1	2	3	4	5	(15)
	twisting/twisting and bending	1	2	3	4	5	(16)
3.	RIGHT ELBOW above shoulder	1	2	3	4	5	(17)
4.	LEFT ELBOW above shoulder	1	2	3	4	5	(18)
5.	RIGHT: HORIZONTAL DISTANCE HAND-SHOULDER clearly more than length of forearm	1	2	3	4	5	(19)
6.	LEFT: HORIZONTAL DISTANCE HAND=SHOULDER clearly more than length of forearm	1	2	3	4	5	(20)
7.	RIGHT HAND: LIFTING/FORCE involved IF YES: weight/force __ __ poonds	1	2	3	4	5	(21) (22-23)
8.	LEFT HAND: LIFTING/FORCE involved IF YES: weight/force __ __ poonds	1	2	3	4	5	(24) (25-26)
9.	BOTH HANDS: LIFTING/FORCE involved IF YES: weight/force __ __ poonds	1	2	3	4	5	(27) (28-29)
10.	PRECISION involved	1	2	3	4	5	(30)
11.	EXTREME POSITIONS OF RIGHT HAND	1	2	3	4	5	(31)
12.	EXTREME POSITIONS OF LEFT HAND	1	2	3	4	5	(32)

IF SCORED 3,4,or 5 on Question #11 or #12:

	SUPINATION N/Y LEVEL	PRONATION N/Y LEVEL	ULNAR DEVIATION N/Y LEVEL	RADIAL DEVIATION N/Y LEVEL	WRIST-EXTENSION N/Y LEVEL	WRIST-FLEXION N/Y LEVEL	
RIGHT	0 1 1 2 3	0 1 1 2 3	0 1 1 2 3	0 1 1 2 3	0 1 1 2 3	0 1 1 2 3	(33-44)
LEFT	0 1 1 2 3	0 1 1 2 3	0 1 1 2 3	0 1 1 2 3	0 1 1 2 3	0 1 1 2 3	(45-56)