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US WEST COMMUNICATIONS (USWC)
PHOENIX, ARIZONA
MINNEAPOLIS/StPAUL, MINNESOTA
DENVER, COLORADO

NIOSH INVESTIGATORS:
THOMAS HALES, MD
STEVEN SAUTER, PhD
MARTY PETERSEN, PhD
VERN PUTZ-ANDERSON, PhD
LAWRENCE FINE, MD, DrPH
TROY OCHS, MS
LARRY SCHLEIFER, EdD
BRUCE BERNARD, MD, MPH

I. SUMMARY

In July 1989, the Hazard Evaluations and Technical Assistance Branch of the National Institute for Occupational Safety and Health (NIOSH) received a joint request from the Communication Workers of America (CWA) and US West Communications (USWC) to evaluate how the use of video display terminals (VDTs) affects the health of Directory Assistance Operators (DAOs). The primary concern of both USWC and CWA was the effect on the operators' musculoskeletal system. To address this primary concern, a cross-sectional study of 533 workers from five distinct job titles employed within three metropolitan areas (Phoenix, Minneapolis/St. Paul, and Denver) was conducted.

Assessment of the upper extremity (UE) musculoskeletal system utilized symptom questionnaires and physical examinations. Data on demographics, individual factors (medical conditions and recreational activities), work practices, work organization, and psychosocial aspects of work, including electronic performance monitoring, were obtained from all participants by questionnaire. For one of the employee groups, the total number of keystrokes per day was generated from company computer records. The physical workstation was assessed using checklists of workstation configuration, and postural data were obtained from employees while they operated their VDTs.

Two types of musculoskeletal outcomes were defined for analysis:

1) Potential Work-related UE Musculoskeletal Disorders (<u>UE Disorders</u>) defined by physical examination and questionnaire,
2) UE Musculoskeletal Symptoms (<u>UE Symptoms</u>) defined by questionnaire alone based on a cumulative score of symptom duration, frequency and intensity.

Associations between workplace factors and UE Disorders were assessed by multiple logistic models generated for each of the four UE areas (neck, shoulder, elbow, hand/wrists), and for any work-related UE musculoskeletal disorder. Associations between workplace factors and degree of UE Symptoms were assessed by multiple linear models generated for each of the four UE joint areas (neck, shoulder, elbow, and hand/wrist). The physical workstation and posture information was not included in these analyses due to methodological limitations described in

Appendix C. Five-hundred-thirty-three (93%) of 573 selected employees participated in the study. Fifteen employees were excluded from the analysis because they were employed at their current job less than 6 months. The mean age of the remaining participants was 38 years, and the mean seniority on the current job was 6.3 years. Seventy-eight percent of participants were female, and 74% described themselves as "white."

One-hundred-eleven (22%) met our case definition for potential work-related UE musculoskeletal disorders. Probable tendon-related disorders were the most common (15% of participants), followed by probable muscle-related disorders (8%), probable nerve entrapment syndromes (4%), ganglion cysts (3%), and joint-related disorders (3%). The hand/wrist was the area most affected (12% of participants), followed by the neck area (9%), the elbow area (7%), and the shoulder area (6%). Phoenix workers had the highest prevalence of disorders (25%), followed by Denver workers (21%), and Minneapolis/StPaul workers (17%). Loop Provisioning Center (LPC) employees had the highest prevalence of disorders (36%), followed by Recent Change Memory Administration Center (RCMAC) employees (25%), Directory Assistance Operators (DAO) (22%), Centralized Mail Remittance (CMR) employees (20%), and Service Representatives (SR) (6%).

The OSHA 200 Log data and concerns expressed by USWC and CWA suggested that the DAOs would have the highest prevalence of disorders. This expectation was not supported by our findings. Although 22% of DAOs had musculoskeletal disorders which were potentially work-related, this prevalence was not higher than two of the four comparison groups utilized in this study and was similar to the prevalence rates reported in some previous studies of VDT users.

The following variables had statistically significant associations in the final models ($p<0.05$) with at least one of the outcome measures, although most of these associations have small point estimates (odds ratios) or small portions of the total variance explained (R-squared).

Of the three demographic factors, female gender was associated with degree of neck and shoulder symptoms, and non-white race was associated with elbow disorders. Of the nine medical history factors, five were frequently reported and entered into the final models. A history of physician-diagnosed thyroid conditions was associated with hand/wrist disorders, and a history of physician-diagnosed rheumatoid arthritis was associated with degree of elbow and hand/wrist symptoms. Recreational activities were not associated with UE disorders or degree of UE symptoms.

For the nine work practice variables, use of bifocals at work was associated with neck disorders, while use of glasses or contact lenses at work was associated with degree of elbow symptoms. For the 10 work organizational factors, overtime in the past year was negatively associated with degree of shoulder symptoms, and increasing number of hours spent at the VDT workstation per day was negatively associated with degree of hand/wrist symptoms.

For the 29 psychosocial variables, seven were associated with UE Disorders: fear of being replaced by computers, jobs which required a variety of tasks, increasing work pressure, lack of a production standard, lack of job diversity with little decision making opportunity, high information processing demands, and surges in workload. Seven psychosocial variables were also associated with degree of UE Symptoms: four mentioned previously (increasing work pressure, lack of job diversity with little decision making opportunity, high information processing demands, and surges in workload), plus uncertainty about one's job future, lack of co-worker support, and lack of supervisor support.

None of the eleven electronic performance monitoring variables were associated with UE Disorders in the final models, but five variables were associated with degree of UE Symptoms. More UE musculoskeletal symptoms were experienced in individuals who perceived that the monitoring system: 1) caused less socializing with co-workers, 2) rarely helped work performance and motivation, 3) caused more supervisor complaints regarding work performance, 4) closely monitored their work quality, or 5) caused more work.

Information to estimate the total keystrokes per day was available for 174 (71%) directory assistance operators. Increasing total keystrokes per day was not associated with UE Disorders or UE Symptoms in the final models. The relative low number of keystrokes per day performed by DAOs (mean 15,950) limits the ability to generalize these results to CMR employees or other data entry employees who may perform up to 80,000 keystrokes per day.

Efforts to analyze the effects of employee postural and workstation factors were thwarted by methodological constraints (Appendix C).

Several sources of potential bias could have influenced the results and interpretation of this study, including study design limitations, disease misclassification, and exposure misclassification. The very high prevalence of disorders among LPC employees and the much lower prevalence of disorders among SR raises the possibility that many of the workplace factors associated with UE Disorders and UE Symptoms are surrogates for these job titles. The study's cross-sectional study design cannot determine whether self-reported working conditions were causally related to work-related musculoskeletal outcomes. For example, did the negative psychosocial variables cause a musculoskeletal disorder, or did the negative psychosocial variables result from acquiring a musculoskeletal disorder? In addition, a total of 72 independent variables were analyzed for associations with nine dependent variables opening the possibility for associations due to chance (Type I error). Further discussion of these and other biases are described in Section VI of this report.

On the basis of this evaluation, NIOSH investigators concluded that a high prevalence of potential work-related musculoskeletal disorders and symptoms was observed in this study. Factors associated with these disorders included demographics, prior medical conditions, work practices, psychosocial aspects of the workplace, and electronic performance monitoring. A few of the associations are inconsistent to those reported in the literature. Almost all of the physical workstations observed in this study were of high ergonomic quality, therefore we could not evaluate its contribution to work-related upper extremity musculoskeletal disorders and upper extremity musculoskeletal symptoms. This study adds to the evidence that the psychosocial work environment is related to the occurrence of work-related upper extremity musculoskeletal disorders and upper extremity musculoskeletal symptoms. Recommendations to improve working conditions, and possibly prevent and control musculoskeletal disorders are contained in Section VIII of this report.

KEY WORDS: SIC 4813 (Telecommunications), video display terminals, office automation, ergonomics, psychosocial, work stress, electronic performance monitoring, keystrokes, musculoskeletal disorders, tendinitis, carpal tunnel syndrome.

II. INTRODUCTION

In July 1989, the NIOSH Health Hazard Evaluation program received a joint request from US West Communications (USWC) and the Communication Workers of America (CWA) to evaluate "...how work may impact the health of Directory Assistance Operators (DAO)." NIOSH limited the health outcome to the musculoskeletal system because this was the primary concern of USWC and CWA. In addition, to obtain comparison groups for many of the work organization and psychosocial aspects of work, the study group was expanded to include other employee groups utilizing video display terminals (VDTs) and performing keyboard tasks for at least six hours per day. The other employee groups included Service Representatives (SR), Loop Provisioning Center (LPC) employees, Recent Change Memory Administration Center (RCMAC) employees, and Centralized Mail Remittance (CMR) employees.

Site-visits of four potential participating cities were conducted and information was gathered regarding the type of workstations, job requirements, and health data. In May 1990, study protocols were distributed to USWC, CWA, and three individuals outside of NIOSH with expertise in the areas of VDT use and musculoskeletal disorders. The protocol was modified to incorporate many of the suggestions offered by the reviewers. During the six month period, June 1990 to December 1990, data were collected from the three metropolitan areas selected for participation (Phoenix, Minneapolis/St Paul, and Denver). At each location, upon completion of the physical examination, the NIOSH physician discussed the examination's findings with the individual employee. An interim letter was distributed to CWA and USWC in January 1991, and preliminary results were discussed with the joint CWA-USWC ergonomics committee in January, 1992.

III. BACKGROUND

During the past decade musculoskeletal problems attributed to VDT use have been reported in the United States and other countries.[1-7] Musculoskeletal problems among VDT users have been linked to workplace ergonomic demands (eg constrained postures) in numerous studies,[8-11] however other investigations have provided equivocal support for these findings.[12-16] In particular, the psychosocial work environment (eg job control, social support) of VDT users has received increasing attention, with many studies finding relationships of the psychosocial work environment with health complaints.[17-22] Few scientific studies, however, have examined the role of these two categories of risk factors interactively.[12-13]

The objectives of this study were to 1) determine the prevalence of potential work-related UE musculoskeletal disorders among five employee groups utilizing VDTs, 2) determine the association of demographic, individual factors, work practices, work organization, psychosocial factors, electronic performance monitoring, and keystrokes per day with these disorders, and 3) to suggest prevention strategies to control the occurrence and severity of these disorders.

IV. METHODS

A. CITY AND PARTICIPANT SELECTION

Disease prevalence among employee groups was estimated using the company-maintained injury and illness records (Occupational Safety and Health Administration [OSHA] 200 Logs). Based on these estimates, sample size calculations were performed to detect a disease prevalence difference between DAOs and the other employee groups of 2.5 using the standard alpha (0.05) and beta (power) (0.80).[23] The city selection was narrowed to locations employing at least 125 DAOs, with at least 25 individuals in each comparison group: SR, LPC, RcMAC, and CMR. Six metropolitan areas qualified. Three metropolitan areas were selected for study: two (Phoenix and Denver) with a relatively high CTD incidence, and one (Minneapolis/StPaul) having a relatively low CTD incidence (based on the OSHA 200 logs).

For three of the employee groups, RcMAC, LPC, and CMR, all employees working the day of the NIOSH site-visit were asked to participate. The remaining two employee groups, DAO and SR, had more employees working than the required sample size, so a random sample of employees working the day of the NIOSH visit was selected.

B. MUSCULOSKELETAL OUTCOMES

A self-administered questionnaire designed to elicit data on musculoskeletal symptoms of the upper extremity (UE) was distributed to participating employees. If discomfort had been experienced in the past year, more information was ascertained regarding the discomfort's onset, duration, frequency, and severity. All employees completing the questionnaire were offered a physical examination of their upper extremities. The examination consisted of inspection, palpation, passive movements, resisted movements, and a variety of maneuvers to define UE musculoskeletal conditions standardized through its use in other NIOSH evaluations (Table 1). Four physicians were trained to administer the UE examinations and were blinded to the individual's questionnaire responses.

Based on the questionnaire and physical examinations, two types of musculoskeletal outcomes were defined for analysis.

1. **Potential Work-related UE Musculoskeletal Disorders (UE Disorders)** defined by physical examination and questionnaire.

Study participants were divided into cases and non-cases of potential work-related UE musculoskeletal disorders according to the criteria listed in Table 2.

2. **UE Musculoskeletal Symptoms (UE Symptoms)** defined by questionnaire.

Given the fluctuations of musculoskeletal disorders over a 12-month period, a case definition which requires positive physical examination findings may cause false negative results. In addition, employees may over- or under-report the work-relatedness of their symptoms. Therefore, a second method of classifying the UE musculoskeletal disorders was generated using only the symptom questionnaire. A cumulative score of the discomfort's duration, frequency, and severity was calculated separately for the neck, shoulder, elbow, and hand/wrist (Table 3). The UE symptoms scores did not include work-related criterion. Because the response scales for the duration, frequency, and severity questions varied in terms of number of response options, they were standardized prior to summation.[34]

C. DEMOGRAPHICS AND INDIVIDUAL FACTORS

The age, race, and gender of all participants were ascertain by the questionnaire. In addition, the questionnaire asked the total number of hours per week spent on hobbies and recreational activities, and whether the participant had any of a number of physician-diagnosed conditions reported to be associated with carpal tunnel syndrome (rheumatoid arthritis, diabetes mellitus, thyroid disease, disk disease in the low back or neck, alcoholism, gout, lupus, and kidney failure).

D. WORK PRACTICES AND WORK ORGANIZATION

Work practice and work organization characteristics were assessed by questionnaire. The work practice variables included the use of glasses or contact lenses, bifocals, trifocals, and granny glasses; typing skill and technique; length of time sitting continuously in the chair; frequency of arising from the chair; and seniority on the current job. The work organization variables consisted of the number of overtime hours, co-worker use of the same workstation, task rotation, hours spent at the VDT workstation, hours spent typing, and the number and type of work breaks.

E. PSYCHOSOCIAL

Several scales from a separate NIOSH questionnaire were incorporated into the present questionnaire to assess the psychosocial aspects of the work environment.[35] These scales have had extensive use in occupational stress research and prior NIOSH studies. In addition, items and scales from two surveys addressing the psychosocial work climate (the Job Characteristics Inventory[36] and the Job Diagnostic Survey[37]) were included in the questionnaire.

In total, psychosocial components of the questionnaire included 22 scales (such as job control, work pressure, workload, etc.), and four single-item variables (Appendix A). All scales were factor analyzed to assure uni-dimensionality and were further analyzed to determine their internal consistency using Chronbach alpha coefficients.[38] Additionally, three single item electronic performance monitoring questions answered by all participants were analyzed as part of this section.

F. ELECTRONIC PERFORMANCE MONITORING

Employees who worked under electronic performance monitoring or productivity standards were asked to respond to a series of questions regarding its fairness, accuracy, and its effects on their work environment. These scales were adopted from a University of Wisconsin study of work monitoring among telecommunication workers.[39] In total, 24 electronic performance monitoring items were grouped into seven scales variables and four single-item variables (Appendix B). All scales were factor analyzed to assure uni-dimensionality and were further analyzed to determine their internal consistency using Chronbach alpha coefficients.[38] Two of the scales, composed of items which varied in terms of number of response options, were standardized prior to summation.[34]

G. KEYSTROKE INFORMATION

The number of keystrokes per day could be estimated for the DAO employee group. As part of the electronic performance monitoring for DAOs, computers monitored the number of calls taken per day, the total "on-line" time, and the number of searches required to find the correct telephone number (search ratio). Given the search ratio, the number of first and subsequent searches per day could be calculated. The number of keystrokes performed during the first and subsequent searches were collected from the "SMART" computer monitoring program described below. Adding the number of keystrokes per day for the first and subsequent searches allowed an estimation of the number of keystrokes per day.

For the Denver DAOs, the SMART program was designed to provide feedback to operators regarding the efficiency of their number search strategy. Operators were notified upon initiation of SMART monitoring, which occurred for the complete day, on three separate days during the month. Among other things, the program calculated the precise number of keystrokes for the first search and all subsequent searches. Therefore, for the Denver DAO subgroup, precise information was available on the number of keystrokes per day.

H. PHYSICAL WORKSTATION AND POSTURAL MEASUREMENTS

The physical workstation was assessed using checklists of workstation configuration, and postural data were obtained from employees while they operated their VDTs. Efforts to analyze the effects of employee postural and workstation factors were thwarted by methodological constraints (Appendix C).

I. STATISTICAL ANALYSIS

The statistical analysis describe below is schematically represented in Figure 1.

Step 1; Independent variables were grouped into 6 sets: 1) demographic; 2) work practices, work organization, and individual factors; 3) psychosocial; 4) electronic performance monitoring; 5) DAO keystrokes per day; and 6) Denver DAO keystrokes per day. Univariate analysis of independent variables within each of the six sets was conducted to determine their association with UE Disorders and UE Symptoms, as described in section B above. Independent variables were then excluded from these sets and excluded from further statistical analysis if they did not appear to be associated with UE Disorders or UE Symptoms (p-value >0.1). P-values were calculated using Student's t-test, analysis of variance, likelihood ratio chi-square test, or Pearson's chi-square test, as appropriate.

Step 2: Within each of the six variable sets, all independent variables with a p-value $\leq$0.1 were entered into either logistic or linear models to examine their effects while controlling for the effects of other variables. Logistic modeling was used to examine effects on UE Disorders, while linear modeling was used to examine effects on UE Symptom scores. A backward elimination procedure was used in both types of models to remove non-associated variables (p-value >0.05).

Step 3: All independent variables surviving Step 2 were combined together for subsequent analysis. Again backward elimination removed non-associated variables (p-value >0.05). Because the sample size was smaller for the electronic performance monitoring, DAO keystrokes per day, and Denver DAO keystrokes per day variables (approximately 450, 174 and 37 participants, respectively), these variables were not included at this stage in order to maximize power and reliability.

Step 4a: Electronic performance monitoring variables remaining after Step 2 were combined with the variables from Step 3. Again backward elimination was used, first on the monitoring variables and then on all remaining variables, to remove non-associated variables (p-value >0.05).

Step 4b: Keystrokes per day for all DAOs remaining after Step 1, were combined with the variables from Step 3 and tested simultaneously. If the p-value for this test was less than 0.05, backward elimination removed non-associated variables.

Step 4c: Keystrokes per day for Denver DAOs, if significant after Step 1, were combined with the variables from Step 3, and tested simultaneously. If the p-value for this simultaneous test was less than 0.05, backward elimination removed non-associated variables (p-values greater than 0.05).

Associations are reported as odds ratios (OR) with a 95% confidence interval (95% CI) for the logistic models, and as partial R-squares (R^2) for the linear models. Odds ratios with a value of less than 1.05 are not reported. Many of the exposure (independent) variables, particularly the psychosocial and electronic performance monitoring variables, have scaled values. The OR for these scaled variables represent the increased risk of disease for one increment within the scale. For example, if the response options for an independent variable ranged from "1" to "5", the OR represent the risk of disease for those responding "2" compared to those responding "1", or "5" to "4", but not of "5" to "1".

V. RESULTS

Overall, 533 (93%) employees agreed to participate. The Denver employees, and the DAO employees had the highest rates of participation (97% for both, Table 4). Fifteen employees were excluded because they had been at their current job less than six months, leaving a total of 518 employees. The actual sample size of each final model was slightly smaller due to some employees not responding to all variables in the questionnaire.

Descriptive data for potential work-related UE musculoskeletal disorders and the six independent variable sets are reported below. Variables in the final models are reported together with the descriptive data for each of the six independent variable sets.

A. MUSCULOSKELETAL DISORDERS

Overall, 111 (22%) employees met our case definition for potential work-related UE musculoskeletal disorders (UE Disorders). Phoenix employees had the highest prevalence of disorders (25%), followed by Denver employees (21%), and Minneapolis/StPaul employees (17%) (Table 5). Loop provisioning center employees had the highest prevalence of disorders (36%), followed by RcMAC (25%), DAO (22%), CMR (20%), and SR (6%) (Table 5).

Probable tendon-related disorders (15%) were the most common type based on positive physical examination findings, followed by probable muscle-related [tension neck syndrome and neck trigger points (8%), probable entrapment neuropathies (4%), joint-related findings (3%), and ganglion cysts (3%)] (Table 6).

1. Neck

Overall, 9% of employees had neck disorders. Denver employees and the LPC employees had the highest prevalences, 11% and 17%, respectively (Table 7).

2. Shoulder

Overall, 6% of employees had shoulder disorders. Phoenix employees and the RcMAC employees had the highest prevalences, 8% and 9%, respectively (Table 8).

3. Elbow

Overall, 7% of employees had elbow disorders. Denver and Phoenix employees had similar prevalences, 9% and 8% respectively. The DAO and LPC employees had the highest prevalences, both 9% (Table 9).

4. Hand/Wrist

Overall, 12% of employees had hand/wrist disorders. All three metropolitan areas had similar prevalences (12% and 13%), while the LPC employees had the highest prevalences (20%) and the SR the lowest (1%) (Table 10).

B. DEMOGRAPHIC AND INDIVIDUAL FACTORS

The mean age of participants was 38 years, with a mean seniority at their job of 6.3 years. Most of the participants were female (78%), and 74% described their race as white. In the logistic models, non-white race was associated with elbow disorders [odds ratio (OR)=2.4, 95% confidence interval (95% CI)=1.2, 5.0] (Table 11). In the linear models female gender was associated with increasing neck and shoulders symptoms (R^2=0.03 for both) (Table 12).

Participating employees spent a mean of 12 hours per week on recreational activities or hobbies. This factor was not significantly associated with any of the five models for UE disorders (neck, shoulder, elbow, hand-wrist, and any UE area), or any of the four models for UE symptoms (neck, shoulder, elbow, and hand-wrist).

Thyroid conditions were reported by 26 (5%) of participants, while rheumatoid arthritis was reported by 32 (6%) (Table 13). Presence of thyroid disorders was a strong predictor of hand/wrist disorders (OR=3.9; 95% CI=1.5, 9.9) (Table 11). Rheumatoid arthritis was associated with increasing elbow and hand/wrist symptoms (R^2=0.01 for both) (Table 12).

C. WORK PRACTICES AND ORGANIZATION CHARACTERISTICS

Sixty-two percent of employees wore glasses or contact lenses at work, and 10% wore bifocals (Table 14). Forty-eight percent stated their typing skill as "medium" (between 30 and 60 words per minute), and 70% had a "touch type" technique (Table 14). The mean number of times per day arising from their chair was 12, while the median length of time sitting in the chair continuously was 1 to 2 hours (Table 14). Use of bifocals at work was associated with neck disorders (OR=3.8, 95% CI=1.5, 9.4) (Table 11). Use of glasses or contact lenses at work was associated with increasing elbow symptoms in the linear models (R^2=0.02) (Table 12).

Seventy-four percent of employees had worked overtime in the past year, 69% had co-workers utilizing their workstations, and 13% stated they rotated tasks during the workday (Table 15). A mean of 7.3 hours was spent at their VDT workstations, of which 7.0 hours was spent typing. There was a mean of 4.2 brief breaks and 2.5 longer breaks during the workday (Table 15). Overtime in the past year had a negative association with increasing shoulder symptoms (R^2=0.01), and increasing number of hours spent at the VDT workstation per day had a negative association with increasing hand/wrist symptoms (R^2=0.02) (Table 12).

D. PSYCHOSOCIAL

The mean and range scores for the 29 psychosocial variables are listed in Table 16. In the logistic models, seven variables accounted for 14 associations with UE Disorders:

six for the neck, one for the shoulder, three for the elbow, one for the hand/wrist, and three for any upper extremity (Table 11). Fear of being replaced by computers was the most consistent, being associated with neck (OR=1.5, 95% CI=1.2, 2.0), shoulder (OR=1.5, 95% CI=1.1, 2.0), elbow (OR=1.5, 95% CI=1.1, 2.0) and upper extremity (OR=1.3, 95% CI=1.1, 1.5) disorders. Jobs requiring a variety of tasks were associated with neck (OR 1.4, 95% CI=1.1, 1.7) and upper extremity disorders (OR 1.2, 95% CI=1.0, 1.4). Increasing work pressure was associated with neck (OR=1.2, 95% CI=1.0, 1.3) and upper extremity disorders (OR=1.1, 95% CI=1.0, 1.2). Routine work lacking decision making opportunities was associated with neck (OR=1.6, 95% CI=1.3, 2.0) and elbow disorders (OR=1.4, 95% CI=1.1, 1.8), and high information processing demands was associated with neck (OR=1.3, 95% CI=1.0, 1.6) and hand/wrist disorders (OR=1.2, 95% CI=1.1, 1.4). Lack of a production standard was associated with neck disorders (OR=3.5, 95% CI=1.5, 8.3), while surges in workload was associated with elbow disorders (OR=1.2, 95% CI=1.0, 1.3).

In the linear models, seven variables accounted for 13 associations with degree of UE Symptoms: two for the neck, one for the shoulder, five for the elbow, and five for the hand/wrist (Table 12). Four of these seven variables also had associations in the logistic modeling analysis (work pressure, surges in workload, routine work, and high information processing demands). The three variables which had associations only with increasing UE Symptoms included: 1) uncertainty about one's job future [neck (R^2=0.01), elbow (R^2=0.02), and hand/wrist symptoms (R^2=0.02)], 2) lack of co-worker support [elbow symptoms (R^2=0.01)], and 3) lack of supervisor support [hand/wrist symptoms (R^2=0.01)].

E. ELECTRONIC PERFORMANCE MONITORING

Four hundred eighty-one (93%) participants reported computer monitoring for quantity of work performed, while only 42% reported computer monitoring for quality of work performed (Table 16). Four hundred fifty-seven (88%) participants reported the presence of a productivity standard (Table 16) and 57% of those reported it was fair (Table 17). None of the eleven monitoring variables were associated with UE Disorders in the logistic models. Five monitoring variables were associated with increasing UE Symptoms in the linear models (Table 18). Perceptions that the monitoring system resulted in: 1) less socializing with co-workers (R^2=0.01), 2) rarely helping work performance and motivation (R^2=0.02), and 3) more supervisor complaints regarding work performance (R^2=0.02) were associated with increasing neck symptoms. Individuals who perceived that the computer closely monitored their work quality reported increasing shoulder and elbow symptoms (R^2=0.03 and 0.05, respectively), and individuals who perceived that the monitoring system resulted in more work reported increasing elbow symptoms (R^2=0.06). It is important to point out that several of the demographic, individual factors, work organization, and psychosocial variables drop out of the models when the electronic performance monitoring variables are included in the models (compare Tables 12 and 18).

F. KEYSTROKES

Information to estimate the total keystrokes per day was available for 174 (71%) directory assistance operators (DAOs). Phoenix operators averaged the most keystrokes (16,832), followed by Minneapolis/St Paul (16,708) and Denver operators (14,534). Neither the logistic or linear modeling analysis for these 174 operators found an association between increasing total keystrokes per day and UE Disorders or increasing UE Symptoms in the final models.

The SMART program provided precise keystroke information for 37 Denver DAOs. These 37 employees averaged 13,943 keystrokes per day, and this variable was not a predictor for UE Disorders or increasing UE Symptoms.

VI. DISCUSSION

Potential Work-Related Musculoskeletal Disorders

The overall prevalence of potential upper extremity work-related musculoskeletal disorders (by questionnaire AND physical examination) was 22%. Using similar case definitions, other NIOSH studies of high risk employees (meatpacking industry and supermarket scanning cashiers) found prevalence rates of 62% and 51%, respectively.[40,41]

NIOSH investigators have also conducted studies of musculoskeletal disorders among VDT operators. A previous NIOSH study defined potential work-related musculoskeletal disorders by questionnaire alone and found prevalence rates for the upper extremities to be 38%.[4] Prevalence rates based on questionnaires alone tend to be double the rates based on both questionnaires and physical examinations.[43,44] Other studies of newspaper employees utilizing VDTs reported a prevalence of at least 26% for lower arm tendinitis or carpal tunnel syndrome, and 26% suffering from painful hands and wrists.[45,46] It appears, therefore, that the prevalence of UE symptoms and disorders at USWC is similar to the prevalence among VDT users studied by NIOSH researchers,[4,12] and others.[43,46] None the less, 22% of the USWC workforce met the NIOSH definition of a physician-diagnosed upper extremity musculoskeletal disorder. This study did not address the impact these disorders have on productivity and health care costs.

Phoenix employees had the highest prevalence of upper extremity disorders (25%), followed by those in Denver (21%) and Minneapolis/StPaul (17%). Prior analysis of the company maintained OSHA 200 logs found the same order; however, the rate difference between Phoenix and Minneapolis/StPaul was much greater in the OSHA 200 logs. In addition, the OSHA 200 logs suggested that DAOs were the only employee group utilizing VDTs having a problem with work-related UE musculoskeletal disorders. The present study, however, found a very high prevalence of upper extremity disorders among LPC employees, a relatively high prevalence among the RcMAC, CMR, and DAO employee groups, and a very low prevalence among SR. Why the OSHA 200 logs did not detect musculoskeletal problems in these other job titles was not addressed in this study.

The very high prevalence of disorders among LPC employees and the lower prevalence of disorders among SR raises the possibility that many of the workplace factors associated with UE Disorders or UE Symptoms are surrogates for these job titles. Although over 61 workplace variables (72 independent variables minus the 3 demographic, 6 individual factors, and 2 city and job title variables) were collected and analyzed for associations for hand/wrist disorders, current job title had the largest odds ratio. Other than for high information processing demands, our study was unable to identify workplace factors which account for the difference in hand/wrist disorders between employee groups. Other workplace factors could be accounting for these differences between employee groups but were not measured in this evaluation.

Several potential biases may have influenced the prevalence of potential work-related musculoskeletal disorders found in this study.

1) Employees who developed work-related musculoskeletal conditions could have left the workforce or transferred to other jobs resulting in an underestimation of disease prevalence; a "survivor bias" which can occur in any cross-sectional study.[47]

2) Part of the case definition for potential work-related musculoskeletal disorders relied on self-reports of symptoms occurring over the past year and whether they were "work-related." Given the common occurrence of musculoskeletal pain due to non-occupational causes, work-relatedness may have been overestimated. On the other hand, the second part of our case definition required a positive physical finding on examination. Given the fluctuating nature of musculoskeletal disorders, a positive physical finding a number of months prior to our evaluation could have become negative at the time we did our evaluation. This would result in an underestimation of the prevalence. The net effect of these two potential causes of misclassification on the estimate of disease prevalence is unknown. The physical examination and the case definition utilized in this evaluation, while lacking validation, have been

standardized through their use in other studies.[4,40,41,43]

3) This study utilized two separate measures of musculoskeletal outcome: potential work-related UE musculoskeletal disorders (UE Disorders) defined by physical examination and questionnaire, and a cumulative score of UE musculoskeletal symptom frequency, duration, and intensity (UE Symptoms) defined by questionnaire. Despite the former requiring the symptoms be "work-related" and have a positive physical examination, these two outcome measures were positively correlated [as the severity of the symptoms increased (increased frequency, longer duration, increased severity) the prevalence of UE disorders increased], and some of the predictors for increasing UE Symptoms were also predictors for UE Disorders (increasing work pressure for neck, routine work lacking decision making opportunity and surges in workload for elbow, and high information processing demand for the hand-wrist). Nevertheless, many employees scoring toward the higher ends of the symptoms scales did not meet our UE disorders criteria.

We believe the UE Disorders criteria is the stronger outcome measure because it provides a more specific, and more objective measure of self-reported symptom information. However, increasing UE Symptoms as an outcome measure has a few advantages over UE Disorders; a) inclusion of symptomatic employees whose positive physical findings may have resolved, b) avoidance of the relatively arbitrary definition of categorizing symptomatic employees into cases and non-cases, and c) allows for a continuous rather than dichotomous outcome.

As noted previously, UE Symptoms did not require the symptoms to be "work-related." The UE symptoms scores did not include a component of work-relatedness because employees who work in jobs where biomechanical risk factors are obvious may attribute musculoskeletal symptoms to their job more readily than those employed in jobs without obvious biomechanical risk factors. If this occurred, associations between predictor variables and symptoms could be exaggerated.

4) If the self-reported symptoms represent fatigue-related conditions (disease misclassification), one would expect the prevalence of symptoms to increase during the employees' workshift. In the univariate analysis, there was no association between increasing neck, shoulder, elbow, or hand/wrist symptoms and the time into the workshift. In addition, there was no association between neck, elbow, hand/wrist or upper extremity disorders and the time into the workshift. There was, however, an association between shoulder disorders and study participation at the end of the workshift [compared to participation at the beginning and middle of the shifts (OR=1.5 and 4.4, respectively)]. Inclusion of this variable into the shoulder disorders model did not cause any of the other variable to change (Table 11). It is unclear why participants in the middle of their shifts had fewer shoulder disorders than participants at the beginning or end of their shifts.

5) Participation rates varied among employee groups (Table 3). LPC and RcMAC employees had the lowest participation. This lower participation rate could be due, in part, to the fact that their workload continued to accumulate during the time taken to participate in the study. In contrast, for the three other employee groups, particularly the DAOs, the time taken to participate in the study represented a "work-break." If employees in LPC and RcMAC without musculoskeletal symptoms were less likely to participate, this could over-estimate the disease prevalence in these employee groups. Given the generally high participation rates among all employee groups, however, the magnitude of this potential bias is probably small.

Other Limitations

A total of 72 independent variables [demographics (3), city and job title (2), individual factors (6), work habits (9), work organization (10), psychosocial (29), electronic performance monitoring (11), and keystrokes per day (2)] were analyzed in the univariate analysis (Step 1). Despite our criterion for inclusion or removal from a model being consistent with most scientific studies (p-value <0.05), the large number of independent variables opens the possibility for false positive associations due to chance (Type I error). For this reason, the term "statistical significance" has been generally avoided in this report. Distinguishing "causal" versus "chance" associations is aided by the 1) strength of the association, 2) consistency of the association with the reported literature, 3) the biological plausibility, and 4) specificity of the health outcome. We have considered these factors in the subsequent discussions of the associations found in this study.

In addition, the study's cross-sectional design can only identify associations; it cannot clearly distinguish cause vs effect. This point is especially important for the exposure variables which rely on self-reported perceptions of the work environment.

Demographics

In the linear models women were at higher risk for having neck and shoulder symptoms. Other studies have also found female gender as a risk factor for UE musculoskeletal disorders,[4,48-51] but most were unable to study men and women performing the same job. The current study found female gender as a risk factor in jobs where men and women performed the same job tasks. The logistic modeling analysis (UE Disorders), which required positive physical examination findings, failed to find this association, suggesting that women may consider their musculoskeletal symptoms more severe, report their symptoms earlier and more accurately, or have more non-occupational upper extremity usage than men.

Non-white race was associated with elbow disorders in the logistic model. In a univariate analysis of musculoskeletal disorders in the poultry industry, African-Americans were found to have a higher prevalence of upper extremity disorders.[52] However, when the ergonomic demands of the job were entered into a multiple logistic models, race was not a statistically significant factor in the poultry study.[53] As with many other associations in this study, the relationship between race and musculoskeletal disorders could represent a city-job title surrogate or statistical artifact.

Although advancing age has been reported to be a significant risk factor for musculoskeletal disorders in the general population,[50-51] this study, and others evaluating VDT workers, found no association between age and musculoskeletal disorders or symptoms in the final models. Survivor bias (described above) could be one possible explanation.

Individual Factors

Although recreational activities have been associated with musculoskeletal disorders,[52] this study, like most NIOSH studies, did not find recreational activities to be an important confounding variable for UE musculoskeletal disorders.[40] This potential confounding variable was controlled by collecting information on the total number of hours spent on recreational activities. In both the logistic and linear models, this factor was not significantly associated with work-related disorders or symptoms in the final models. For the logistic model, this finding may be due, in part, to our case definition, which excluded individuals previously injured in a symptomatic joint area or who had incurred the symptoms prior to employment at USWC. In addition, some employees may have benefitted from the conditioning effect resulting from certain recreational activities, canceling the detrimental effect some employees may have experienced.[54] Participants responded to questions regarding physician diagnoses of medical conditions reported to be associated with carpal tunnel syndrome. Gout, kidney failure, lupus, and disc disease in the neck were reported in 2% or less of participants and were excluded from analysis. Rheumatoid arthritis, thyroid disease, disc disease in the low back, diabetes and alcoholism were reported more frequently (Table 13). Reporting a history of physician diagnosed rheumatoid arthritis was associated with increasing hand/wrist and elbow symptoms in the linear models, while a history of thyroid conditions was a predictor of hand/wrist disorders and was also a predictor for increasing neck symptoms. Given the low prevalence of participants meeting our case definition for carpal tunnel syndrome, this finding may suggest that thyroid conditions might be associated with soft tissue structures other than the median nerve. However, given the opportunity for Type I error in this study, other studies need to confirm this finding before conclusions can be drawn between thyroid conditions and hand/wrist disorders. Rheumatoid arthritis is known to affect the hand/wrist area, however effects on the elbow are less common and usually represent long-standing disease. Perhaps proximal radiation of pain from the wrist area could account for its association with elbow symptoms.

A potential bias could have influenced the associations found between medical conditions and musculoskeletal disorders and symptoms. Self reports of physician diagnosed medical conditions were accepted without confirming the condition in individual medical records.

Neither the magnitude or direction of this potential misclassification bias is known.

Work Practices and Work Organization

The association between bifocal use and neck disorders found in this study has been previously reported.[55,56] Bifocal use while using a VDT causes more head movements from keyboard to screen, a backward declination of the head, and increased static loading of the neck muscles.[56] The use of bifocals has been reported to alter the elbow flexion.[56] It is possible that eyewear use was associated with awkward postural adjustments resulting in discomfort in the elbow region.

This study found no associations between UE Disorders or UE Symptoms and self-reported typing skill, typing technique, or hours per day spent at the VDT workstation in the final models. Selection criteria for employee groups required VDT use for at least six hours per day; consequently, the mean VDT use per day was 7.3 hours (SD 0.95) and 97% of individual participants utilized VDTs for at least 6 hours per day. Therefore, there was probably insufficient variation in the length of VDT hours per day to fully evaluate its association with UE Disorders or UE Symptoms. Other studies of VDT use have found dose-response relationships between hours of VDT use and neck and shoulder symptoms,[57] but this association has not been a consistent finding in the literature.

The finding that increasing typing hours per day were protective for hand/wrist symptoms could be due to asymptomatic employees volunteering for overtime, or conversely, symptomatic employees not volunteering for overtime or not being allowed overtime by their supervisors. Both these situations would result in more typing hours per day for the asymptomatic employees. Similarly, the finding that overtime in the past year was protective for shoulder symptoms is probably due to the same self-selection bias. This finding does not invalidate the association between increasing typing hours per day and hand/wrist symptoms identified in other studies.[4,42]

This study corroborates the findings of other studies regarding the lack of an association between UE disorders or symptoms and typing technique (hunt and peck vs touch typing).[4,42] Other studies have found associations between UE symptoms and not getting up from the workstation,[4] but this study found no associations in the final models with the length of time sitting in a chair continuously, or with the number of times arising from the chair per day. In addition, in this study other administrative controls aimed at preventing musculoskeletal disorders (rotating job tasks, providing more frequent work-breaks, and self-regulated work pace) were not protective. Despite the lack of an association between work-breaks and UE Disorders, there is considerable support for their effectiveness in other studies.[58-64]

The work practice and work organization variables were measured by questionnaire rather than direct observation. For some variables (eg. frequency of rest breaks, length of time sitting in the chair, number of times arising from the chair) recall bias could be introduced. The validity for some of these work practices and work organizational variables reported on the questionnaire is unknown, thereby reducing our ability to draw definitive conclusions about the importance, or lack of importance, of these variables.

Psychosocial

Fear of being replaced by computers was associated with four disorders (neck, shoulder, elbow, and any upper extremity), and uncertainty about the job future was associated with increasing symptoms in three areas (neck, elbow, hand/wrist). Clearly, for employees with UE Disorders and UE Symptoms, job security was an important issue. Unfortunately, the study's cross-sectional design cannot distinguish cause from effect. Are concerns about job security causing musculoskeletal disorders, or are concerns over job security due to having a musculoskeletal disorder? A longitudinal study could overcome these cause/effect study design limitations, but given the rapid technological advances in the telecommunication industry with the resulting changes in work environment, this type of study would be quite difficult. In either case, lack of job security has been related to adverse psychological effects and poor physical health in other studies.[65-67]

Work pressure was associated with musculoskeletal conditions in both models: neck and upper extremity disorders in the logistic model, and increasing neck, shoulder, elbow, and hand/wrist symptoms in the linear model. This finding supports earlier studies that found work pressure contributing to adverse health outcomes among VDT operators.[13,68-69] However, the modest strength of the association found in our models suggests that reducing the work pressure would have only a modest effect on the prevalence of upper extremity musculoskeletal disorders.

Jobs which require a variety of tasks were associated with neck and any upper extremity disorders while routine work lacking decision making opportunities was associated with increasing elbow and hand/wrist symptoms, and neck disorders. Table 16 indicates that, in general, work tended to be rated as quite routine. For this reason, we speculate that task variety may not have provided the relief from musculoskeletal conditions that would normally have been anticipated. In addition, some groups of VDT users with extremely varied tasks (eg newspaper reporters) have rates of disorders similar to the VDT users in this study.[4,42]

Information processing demands were associated with hand-wrist disorders and hand-wrist symptoms, and neck disorders in the logistic model. This association identifies a factor which has not been previously investigated as a cause of upper extremity musculoskeletal disorders or symptoms. Other studies examining the effects of information processing demands on the musculoskeletal system would be useful.

Lack of support from co-workers was associated with elbow symptoms, while lack of support from supervisors was associated with hand/wrist symptoms. Many researchers consider social support a powerful buffering mechanism to mitigate the effect of heavy work demands.[70-71] Non-occupational psychosocial stress factors were not ascertained in our evaluation. We cannot, therefore, determine if non-occupational psychosocial stress factors are confounding our findings.

The lack of a productivity standard was a risk factor for neck disorders. This finding supports the opinion that the presence of a production standard, alone, does not create a negative psychosocial environment. On the other hand, most of the employees without production standards worked in LPC. Therefore, the presence of a production standard is confounded by job title (lack of a production standard being a surrogate for job title).

Numerous studies have documented the association between psychological stress and health complaints. However, controversy exists as to whether these health complaints represent an actual increase in disease, an increase in reporting, or somatization. Although several studies have linked psychological stress and medical diseases (peptic ulcer disease,[72] coronary artery disease,[73,74] hypertension,[75,76] and infections[77,78]) only two of these studies addressed the role of psychological stress causing objective signs of upper extremity musculoskeletal disease.[18,20] Although the mechanism of effect has yet to be clearly delineated, this study points to the needs to address psychological factors, especially work pressure and job insecurity, in efforts to control musculoskeletal disorders among VDT workers.

Electronic Performance Monitoring

Electronic performance monitoring at USWC tracks an individual's performance, which is then used as a component of employee evaluations. Advocates justify its presence as a means to increase productivity, provide timely employee feedback, and generate objective data for employee evaluations.[79] Detractors argue, on the other hand, that computer monitoring may lead to stress by encouraging competition and unrealistic performance expectations, diminishing opportunities for social interaction, and invading privacy. In this study, the presence of computer monitoring alone was not associated with musculoskeletal disorders or symptoms. However, increased neck, shoulder, and elbow symptoms were reported by individuals who perceived the computer monitoring as: 1) closely monitoring their work quality, 2) making them work more, 3) rarely helping their work performance or motivation, 4) invading the social aspects of their job, or 5) resulting in negative feedback from their supervisor. Monitoring was most strongly associated with neck symptoms. If monitoring is causally associated with the development of symptoms, it may be possible, with further study, to administer monitoring systems without creating these adverse psychological states.

Keystrokes

In this study, the number of keystrokes per day was not a risk factor for UE musculoskeletal disorders or UE musculoskeletal symptoms in the final models. It must be remembered, however, that keystroke information was available only for DAOs; DAOs typed a mean of 15,950 keystrokes per day (range 11,304 to 22,875; std dev 2,410).

This finding cannot be generalized to CMRs or other data entry employees who may perform up to 80,000 keystrokes per day.

Physical workstation

Most employee groups participating in the study had adjustable furniture to accommodate individual differences, and all renovated workstations were of high ergonomic quality. This lack of variance did not allow our study to evaluate the relationship between the physical workstation and UE musculoskeletal disorders or symptoms. Other studies have documented the importance of biomechanical (ergonomic) factors causing work-related musculoskeletal disorders in VDT workers.[8-11]

Statistical

In this study many of the independent (exposure) variables are moderately or highly related to each other. The variables in the final models represent those with the strongest associations with UE Disorders and UE Symptoms using our model selection techniques. However, many of the independent variables could be replaced by another highly related independent variable and account for almost the same amount of dependent variable variance.

Associations between workplace factors and UE musculoskeletal disorders and symptoms found in the final models were derived from the main effects of the independent variables. Relationships between independent variables may be investigated in future analyses. If these analyses alter our scientific interpretation of the data, both USWC and CWA will be notified.

VII. CONCLUSIONS

High prevalences of potential work-related musculoskeletal disorders and UE symptoms were observed in this study. Factors associated with these disorders or symptoms included some variables from all categories investigated (demographic factors, prior medical conditions, work practices, work organization, psychosocial aspects of the workplace, and electronic performance monitoring. Importantly, this study adds to the evidence that the psychosocial work environment can be associated with the occurrence of work-related UE musculoskeletal disorders and UE musculoskeletal symptoms. This association was maintained despite controlling for individual factors (demographics, prior medical conditions, work practices) and work organization characteristics. The limitations of this study must be noted: a) the failure of the findings to support our initial hypothesis that DAOs would have the highest prevalence of work-related musculoskeletal disorders, b) the difficulty determining causality in a cross-sectional study which utilizes self-reports of the work environment and health outcome, c) the large number of independent variables evaluated probably causing some false positive associations (Type I errors), and d) the complex interactions of the psychosocial variables. The association of musculoskeletal outcomes with multiple psychosocial factors was a principle finding of this study. While recommendations for work re-design can be offered based on these findings (See Section VIII - Recommendations) these recommendations are tempered by 1) the modest strength of many of the associations, 2) the methodological limitations described above, and 3) the lack of studies conducted to determine the effectiveness of these interventions.

VIII. RECOMMENDATIONS

A. Continue the joint USWC-CWA Ergonomics Committee. Involvement by top management and union officials demonstrates the commitment USWC and CWA has given to this subject and provides the motivating force for complete implementation of committee recommendations.

B. Continue the local employee-employer ergonomic committees. These committees can provide valuable insight into identifying new or existing hazards, suggest potential solutions, and provide feedback on the effectiveness of various interventions.

C. Continue with purchasing the workstation equipment selected for each employee group based on the recommendations of the USWC-CWA Ergonomics Committee. Our observation indicated that most of the employee groups had adjustable furniture to accommodate individual differences, and that most renovated workstations were of high ergonomic quality. However, a few employees lacked this equipment. Suggested ranges for this equipment can be found elsewhere.[80-82]

D. NIOSH recommends VDT workers have visual testing before beginning VDT work and periodically thereafter to ensure that they have adequately corrected vision to handle such work.[83] In addition, individuals who wear bifocals at work should be evaluated by an eye specialist to determine if the current lenses are appropriate for the job.

E. Despite not finding associations between many work organization variables and UE disorders or symptoms in the final models of this study, the literature suggests they remain important factors to prevent or reduce UE symptoms. Suggested measures to consider include: providing periods of time away from the VDT, allowing more frequent opportunities for employees to get out of their chair, encouraging employees to take more frequent short rest breaks, restructuring work to allow for some component of self-pacing, limiting unwanted overtime, and job rotation.

F. When making changes in the psychosocial work environment, one should consider the following factors:

1. Providing job security. Ambiguity could be reduced in matters of job security and opportunities for career development. Employees need to be clearly informed of promotional opportunities and mechanisms for improving skills or professional growth within the organization, as well as impending organizational developments that may potentially affect their employment.[84]
2. Studies addressing the causes of work pressure, and what interventions are successful at reducing work pressure.
3. Providing job diversity with decision making opportunities, while not overloading employees with an excessive variety of tasks.
4. Fostering co-worker and supervisor support.
5. Reducing information processing loads for employees with excessive demands.
6. Reducing surges in individual workload.

G. For employee groups where performance is electronically monitored, the monitoring should help employee work performance and facilitate positive supervisor and social relationships.

H. The mean number of keystrokes per day performed by the DAO did not seem excessive by comparative standards. For the employee groups where the number of keystrokes per day is much greater (CMR), consider alternative technologies (eg. optical scanners to read the check amount), or changing the work organization (eg. after visualizing the check amount, the operator could strike one key, notifying the computer that the check amount equals the billed amount). Whatever changes are made, their impact on the job's psychological strain needs to be considered.

I. Prompt evaluations of employees with musculoskeletal symptoms by a health care provider should be available without fear of employer reprisal. All recommendations for surgery should generally be based on two independent physician recommendations. Review by the employee's primary physician and the corporate medical director may be helpful. Guidelines for health care providers to evaluate and treat these disorders have been published.[85,86]

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X. AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared by: Thomas Hales, MD, Regional Medical Consultant
NIOSH Region VIII

Steven Sauter, PhD, Chief, Motivation and Stress Research Section
Applied Psychology and Ergonomics Branch

Field Assistance: Linda Cocchiarella, MD, MPH
Occupational Medicine Resident
Cook County Hospital, Chicago

Marile DiGiaccomo, Secretary
NIOSH Region VIII
Steve Douglass, MS
Graduate Student
Miami University

B.J. Haussler, Statistical Assistant
Statistical Services Section
Surveillance Branch

Urs Hinnen, MD, MPH
Visiting Research Scientist
Zurich, Switzerland

Troy Ochs, MS
Graduate Student
University of Cincinnati

Vern Putz-Anderson, PhD
Chief, Psychophysiology and Biomechanics Section
Applied Psychology and Ergonomics Branch

G. Robert Schutte
Health Survey Coordinator
Medical Section
Hazard Evaluation and Technical Assistance Branch

Joan Watkins, DO, MPH
Occupational Medicine Resident
University of Illinois, Chicago

Originating Office: Hazard Evaluation and Technical Assistance Branch
Division of Surveillance, Hazard Evaluations and Field Studies

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APPENDIX C
PHYSICAL WORKSTATION CHARACTERISTICS AND POSTURAL MEASUREMENTS

METHODS

Workstation checklists noted characteristics of chairs, screens, tables, keyboards, and documents on approximately 340 of the 533 (64%) participating employees (Table C-1). In addition, postural measurements (height, distance, and angle) of the neck and upper extremities were taken while employees were working at their workstations (Table C-2). Distances were measured with a ruler, and angles were measured with a goniometer in combination with a carpenter's level. Postural measurements were made for approximately one-half of the participating employees. Selection of employees to collect workstation checklists and angle measurements were not made at random, but rather for the convenience of the investigators. Therefore, some employee groups were over-sampled while others were under-sampled. No employees who participated in the questionnaire and physical examination portion of the study refused to have this information collected. Because of the limitations noted below, the reliability of the analyses linking these conditions to musculoskeletal disorders could not be assured, and thus modeling analyses are not reported.

RESULTS

1. Chair

All of the employees participating in the study had wheels or casters on their chairs, and 99% had some adjustable seat-pan height mechanism. Over 50% of the chairs had back support tension and tilt adjustability and seat-pan tilt adjustability (Table C-3).

2. Keyboard

All of the keyboards were detached from the VDT screen, and 82% had a separate keyboard table. Over 78% of the keyboards had the ability to adjust the height, tilt, front-back, and lateral position (Table C-4). The key configuration was 58% Qwerty, 40% Dvorak, and 3% numeric. A mouse option was present in 4% of participant's workstations. Only 35% had space available for wrist rests or support, and 20% of keyboard edges were sharp.

3. Screen

Sixty-six percent of the VDT screens were located on a separate table, and 95% were positioned in the center of the operator's workstation. Over 50% of the screens had the ability to adjust the height, tilt, front-back, and lateral position (Table C-5).

4. Document

Forty-six percent of participants utilized a document while working at the VDT workstation. Sixty percent of these employees had the document located in the center of their workstation. Ninety-five percent of document holders had lateral adjustability, 69% had front-back adjustability, and 10% had height adjustability.

5. Table and Accessories

Twenty-two percent of tables had sharp edges, and 14% did not have an adequate knee envelope. Sixty percent of participating employees had a foot rest available.

Table C-6 lists the results from the postural measurements.

DISCUSSION

Several factors severely limit interpretation of the postural and physical workstation analysis. 1) Some of the associations may be the result of multi-colinearity (eg confounding) and/or other problems which could not be controlled for in the analysis; for example, electronic keyboard height adjustment mechanisms and inadequate knee envelopes were found only in the Minneapolis/StPaul Directory Assistance Operators. 2) Important sampling bias may have been introduced by measuring employees at only one point in time and by the fact that employees frequently re-adjusted and shared workstations; how reproducible the postural data at various times throughout the day is unknown. 3) Bias could be introduced by individuals with UE symptoms seeking new workstation equipment or changing their posture frequently to accommodate their discomfort. 4) For the employees studied, workstation equipment provided by USWC was, in general, ergonomically correct. Therefore, there may have not been sufficient variance for most physical workstations to adequately evaluate its relationship with UE musculoskeletal disorders.

TABLE 1
Physical Examination Criteria for Various Medical Conditions
HETA 89-299, US West Communications

After performing each passive, active, and resisted maneuver the employee was asked to quantify the discomfort based on a five-point scale: 1=no pain, 2=mild pain, 3=moderate pain, 4=severe pain, and 5=the worst pain ever experienced. Maneuvers were considered significant if the discomfort score was ≥ 3.

NECK

Tension Neck Syn.: - Resisted flexion, or extension, or rotation. Trapezius palpation (spasm or trigger points).

Cervical Root Syn.: - Positive Spurling's maneuver.[24]

SHOULDER

Rotator Cuff Tendinitis:
- Active or resisted arm abduction $\geq$90 deg.
- Deltoid Palpation.

Bicipital Tendonitis: - Positive Yergason's maneuver.[25]

Thoracic Outlet Syn: - Positive hyperabduction and Adson's maneuvers[26-27]

ELBOW

Epicondylitis: - Medial or lateral epicondyle palpation.

Tendonitis: - Pain in the proximal 2/3 of the forearm on resisted wrist or finger flexion or extension.

Radial Tunnel Syn: - Positive Mill's maneuver.[28]

HAND-WRIST

Tendonitis: - Pain in the distal 2/3 of the forearm or hand on resisted wrist or finger flexion or extension.

deQuervain's Dis.: - Positive Finkelstein's maneuver.[29]

Carpal Tunnel Syn.: - Positive Tinel's and Phalen's maneuvers.[30-31]

Guyon Tunnel Syn.: - Positive Guyon Tinel's maneuver.[32]

Ganglion cysts: - Presence of ganglion cysts.

Joint-related: - Decreased MCP, or PIP range of motion ($\leq$100 deg.)

Trigger Finger: - Locking of finger in flexion or palpable tendon sheath ganglion.[33]

TABLE 2
Criteria for Potential Work-Related Cases of Musculoskeletal Disorders
HETA 89-299, US West Communications

- Symptoms of pain, aching, stiffness, burning, tingling, or numbness,
- Symptoms occurred within the past year,
- No previous accident or trauma to the symptomatic joint area,
- Symptoms began after employment with USWC,
- Symptoms occurred on the current job,
- Symptoms lasted for more than 1 week, or occurred at least once a month,
- Posititve physical finding of the symptomatic joint area (Table 1).

Table 3
Cumulative Symptoms Score Calculation for the Neck
HETA 89-299, US West Communications

		Score
Duration:	How long does this NECK problem usually last?	
	less than 1 hour	__1
	1 hour to 1 day	__2
	more than 1 day to 1 week	__3
	more than 1 week to 2 weeks	__4
	more than 2 weeks to 4 weeks	__5
	more than 1 month to 3 months	__6
	more than 3 months	__7
Frequency:	How often have you had this NECK problem in the past year?	
	almost never (every 6 months)	__1
	rarely (every 2-3 months)	__2
	sometimes (once a month)	__3
	frequently (once a week)	__4
	almost always (daily)	__5
Intensity:	On average, describe the INTENSITY of the NECK problem using the scale below.	
	No pain	__1
	Mild pain	__2
	Moderate pain	__3
	Severe pain	__4
	Worst pain ever in life	__5

Cumulative Score = Duration Score + Frequency Score + Intensity Score

NOTE: If no symptoms were experienced over the past year for a particular joint area, the response was scored a "0".

TABLE 4
Participation Rates
HETA 89-299, US West Communications

Job Title	PHX	MSP	DEN	TOTAL
DAO	112 (96%)	58 (98%)	75 (97%)	**245 (97%)**
SR	24 (100%)	24 (92%)	27 (93%)	**75 (95%)**
LPC	24 (71%)	22 (88%)	25 (90%)	**71 (84%)**
RcMAC	31 (94%)	18 (75%)	18 (95%)	**67 (88%)**
CMR	23 (92%)	24 (89%)	28 (100%)	**75 (96%)**
TOTAL	**214 (92%)**	**146 (91%)**	**173 (97%)**	**533 (93%)**

TABLE 5
Prevalence of Potential Work-Related Upper Extremity Musculoskeletal Disorders (UE Disorders) by City and Job Title
HETA 89-299, US West Communications

Job Title	PHX	MSP	DEN	TOTAL
DAO	27%	14%	20%	**22**%
SR	8%	0%	7%	**6**%
LPC	41%	18%	48%	**36**%
RcMAC	21%	29%	28%	**25**%
CMR	25%	30%	8%	**20**%
TOTAL	**25%**	**17%**	**21%**	**22**%

TABLE 6
Types of Musculoskeletal Conditions
Identified on the Physical Examination
HETA 89-299, US West Communications

	#Cases	Total	Percentage
Probable Tendon-related	**76**	**513**	**(15%)**
Rotator Cuff Tendonitis	29	513	(6%)
Bicipital Tendonitis	2	516	(<1%)
Epicondylitis	25	515	(5%)
Proximal Tendonitis	27	516	(5%)
Distal Tendonitis	41	516	(8%)
deQuervain's Disease	10	516	(2%)
Trigger Finger	1	517	(<1%)
Probable Nerve Entrapment	**21**	**513**	**(4%)**
Cervical Root Syndrome	2	515	(<1%)
Thoracic Outlet Syndrome	2	515	(<1%)
Radial Tunnel Syndrome	4	516	(1%)
Carpal Tunnel Syndrome	4	517	(1%)
Guyon Tunnel Syndrome	14	517	(3%)
Ganglion Cysts	**13**	**517**	**(3%)**
Probable Joint Related	**15**	**516**	**(3%)**
Muscle Related	**43**	**516**	**(8%)**

TABLE 7
Prevalence of Potential Work-Related Neck Musculoskeletal Disorders (Neck Disorders) by City and Job Title
HETA 89-299, US West Communications

Job Title	PHX	MSP	DEN	TOTAL
DAO	7%	5%	8%	**7%**
SR	8%	0%	4%	**4%**
LPC	14%	9%	28%	**17%**
RcMAC	10%	11%	22%	**14%**
CMR	0%	9%	4%	**5%**
TOTAL	**8%**	**6%**	**11%**	**9%**

TABLE 8
Prevalence of Potential Work-Related Shoulder Musculoskeletal Disorders (Shoulder Disorders) by City and Job Title
HETA 89-299, US West Communications

Job Title	PHX	MSP	DEN	TOTAL
DAO	10%	0%	8%	**7%**
SR	0%	0%	0%	**0%**
LPC	5%	5%	8%	**6%**
RcMAC	7%	11%	11%	**9%**
CMR	12%	4%	0%	**5%**
TOTAL	**8%**	**3%**	**6%**	**6%**

TABLE 9
Prevalence of Potential Work-Related Elbow Musculoskeletal Disorders (Elbow Disorders) by City and Job Title
HETA 89-299, US West Communications

Job Title	PHX	MSP	DEN	TOTAL
DAO	11%	4%	12%	**9%**
SR	0%	0%	4%	**1%**
LPC	9%	0%	16%	**9%**
RcMAC	3%	6%	6%	**5%**
CMR	6%	0%	4%	**3%**
TOTAL	**8%**	**2%**	**9%**	**7%**

TABLE 10
Prevalence of Potential Work-Related Hand-Wrist
Musculoskeletal Disorders (Hand-Wrist Disorders) by City and Job Title
HETA 89-299, US West Communications

Job Title	PHX	MSP	DEN	TOTAL
DAO	16%	7%	13%	**13%**
SR	0%	0%	4%	**1%**
LPC	18%	14%	28%	**20%**
RcMAC	7%	24%	17%	**14%**
CMR	19%	22%	0%	**12%**
TOTAL	**13%**	**12%**	**12%**	**12%**

TABLE 11
Associations With Potential Work-Related Upper Extremity Musculoskeletal Disorders in the Logistic Regression Model (Methods Section: Step 3)
HETA 89-299, US West Communications

		Odds Ratio	95% Confidence Interval@
NECK: (n=512)			
Use of bifocals		3.8	1.5 - 9.4
Lack of a productivity standard		3.5	1.5 - 8.3
Routine work lacking decision making opportunities		1.6	1.3 - 2.0
Fear of being replaced by computers		1.5	1.2 - 2.0
Job requires a variety tasks		1.4	1.1 - 1.7
High information processing demands		1.3	1.1 - 1.6
Increasing work pressure		1.2	1.0 - 1.3
SHOULDER (n=510)			
Fear of being replaced by computers		1.5	1.1 - 2.0
ELBOW (n=513)			
Race (non-white)		2.4	1.2 - 5.0
Fear of being replaced by computers		1.5	1.1 - 2.0
Routine work lacking decision making opportunities		1.4	1.1 - 1.8
Surges in workload		1.2	1.0 - 1.3
HAND-WRIST (n=511)			
Thyroid condition		3.9	1.5 - 9.9
Current Department*	LPC	1.9	0.7 - 5.1
	DAO	1.1	0.5 - 2.5
	RcMAC	0.8	0.3 - 2.4
	SR	0.1	<0.0 - 0.6
High information processing demands		1.2	1.1 - 1.4
UPPER EXTREMITY (n=512)			
Fear of being replaced by computers		1.3	1.1 - 1.5
Job requires a variety of tasks		1.2	1.0 - 1.4
Increasing work pressure		1.1	1.0 - 1.2

* LPC = Loop Provisioning Center employees
DAO = Directory Assistance Operators
RcMAC = Recent Change Memory Assistance Center employees
SR = Service Representatives
All are compared to the CMR (Centralized Mail Remittance) employees

@ The confidence intervals, like the hypothesis tests, should be viewed with caution because of the large number of independent variables evaluated.

TABLE 12
Associations With Potential Work-Related Upper Extremity Musculoskeletal Symptoms in the Linear Regression Model (Methods Section: Step 3)
HETA 89-299, US West Communications

	R-Squared (R^2)
NECK (n=514)	
Gender (female)	0.03
Increasing work pressure	0.02
City	0.02
Uncertainty about job future	0.01
Thyroid condition	0.01
TOTAL MODEL	**0.11***
SHOULDER (n=514)	
Gender (female)	0.03
Increasing work pressure	0.02
Overtime in the past year	0.01 (neg)
TOTAL MODEL	**0.06**
ELBOW (n=513)	
Routine work lacking decision making opportunity	0.02
Uncertainty about job future	0.02
Surges in workload	0.02
Use of glasses or contact lenses	0.02
Increasing work pressure	0.01
Lack of co-worker support	0.01
Rheumatoid arthritis	0.01
TOTAL MODEL	**0.11**
HAND-WRIST (n=511)	
High information processing demands	0.02
Hours spend at the VDT station per day	0.02 (neg)
Uncertainty about job future	0.02
Routine work lacking decision making opportunity	0.01
Increasing work pressure	0.01
Lack of supervisor support	0.01
Rheumatoid arthritis	0.01
TOTAL MODEL	**0.11***

***** Sum of partial R^2 typically does not equal total model R^2.
(neg) = Negative association

TABLE 13
Prevalence of Physician-Diagnosed Medical Conditions
HETA 89-299, US West Communications

Medical Conditions	Number	Prevalence
Rheumatoid Arthritis	32	6%
Thyroid Disorders	26	5%
Disk Disease in the Low Back	25	5%
Diabetes Mellitus	16	3%
Alcoholism	16	3%
Disk Disease in the Neck	9	2%
Gout	5	1%
Kidney Failure	6	1%
Lupus	0	

TABLE 14
Work Practice Characteristics
HETA 89-299, US West Communications

WORK PRACTICES			Prevalence
Wearing of glasses or contacts when using the VDT			62%
Wearing bi-focals when using the VDT			10%
Wearing tri-focals when using the VDT			3%
Wearing granny glasses when using the VDT			2%
Typing Skill:	Slow	(<30 words/minute)	39%
		Medium (30-60 words/minute)	48%
		Fast (>60 words/minute)	13%
Typing Technique:		Hunt and Peck	23%
		Touch	70%
		Other	7%
Typical length of time sitting continuously in chair			
		Less than 1/2 hour	7%
		1/2 hour to 1 hour	24%
		1 hour to 2 hours	52%
		Greater than 2 hours	17%

	Mean	**Range**
Number of times per day arising from your chair	12	0-100
Seniority at current job (in years)	6.3	0.5-34

TABLE 15
Work Organization Characteristics
HETA 89-299, US West Communications

WORK ORGANIZATION		Prevalence
Overtime in the past year		74%
Overtime in the past month		48%
Overtime in the past week		29%
Do co-workers use your workstation		69%
Rotating tasks during the workday		13%
Ability to regulate work pace:	Never	29%
	Rarely	23%
	Sometimes	29%
	Often	8%
	Almost Always	11%

	Mean	Range
Hours per day spent at the VDT	7.3	0-10
Typing hours per day	7.0	0-10
Number of brief breaks per day	4.2	0-50
Number of longer breaks per day	2.5	0- 7

TABLE 16
Psychosocial Variables*
HETA 89-299, US West Communications

	Mean	Range
Meaningful work	5.1	1-7
Control over amount and quality of work	3.1	1-5
Control over job related matters	2.5	1-5
Skill utilization	2.4	1-5
Control over work policy and materials	2.0	1-5
Participation in work decisions	2.0	1-5
Cooperation between union and mgmt on health issues	2.6	1-4
Job requires a variety of tasks	1.5	1-3
Job satisfaction	SV#	
	Mean	**Range**
Lack of friends and relatives (home) support	1.6	1-5
Little interaction with others	1.8	1-5
Sum of supervisor, co-worker and home support	2.1	1-5
Lack of supervisor support	2.3	1-5
Lack of co-worker support	2.3	1-5
Uncertainty about job future	2.3	1-5
Little interaction with co-workers	2.4	1-5
Customer hostility	2.5	1-5
Replaced by a computer	2.7	1-5
Boring work	2.8	1-5
Surges in workload	3.2	1-5
Workload	3.6	1-5
Increasing work pressure	3.8	1-5
High information processing demands	2.3	1-4
Sum of workload mental demands	2.6	1-4
Routine work lacking decision making opportunities	2.9	1-4
Work requires high mental demands	2.9	1-4
	Prevalence	
Computer monitors quantity	93%	
Computer monitors quality	42%	
Presence of a productivity standard	88%	

* Spaces between variables signify a change in the scale range or scale direction
# Standardized value, see Methods section in text

TABLE 17
Electronic Performance Monitoring Variables*
HETA 89-299, US West Communications

	Prevalence	
Fair productivity standard	57%	
	Mean	**Range**
Control and accuracy of computer monitoring	2.4	1-4
Monitoring rarely helps work performance and motivation	1.1	1-4
Monitoring invades social aspects of the job	2.4	1-4
Monitoring results in more work	1.3	1-4
Monitoring results in negative feedback from supervisor	1.5	1-4
Most recent evaluation on work quantity	1.7	1-4
Most recent evaluation on work quality	1.6	1-4
Difficulty meeting productivity standard	1.6	1-3
Computer closely monitors work quantity	SV#	
Computer closely monitors work quality	SV	

* Spaces between variables signify a change in the scale range or scale direction
# SV = Standardized value, see Methods section in text

TABLE 18
Monitoring Variable Associations With Potential Work-Related Upper Extremity Musculoskeletal Symptoms in the Linear Regression Model
(Methods Section: Step 4a)
HETA 89-299, US West Communications

NECK (n=393)	**R-Squared (R^2)**
Monitoring rarely helps work performance and motivation	0.02
Monitoring results in negative feedback from supervisor	0.02
Monitoring invades social aspects of the job	0.01
Gender	0.05
Increasing work pressure	0.02
City	0.02
TOTAL MODEL	**0.16***
SHOULDER (n=162)	
Computer closely monitors work quality	0.03
Gender	0.04
TOTAL MODEL	**0.08***
ELBOW (n=149)	
Monitoring results in more work	0.06
Computer closely monitors work quality	0.05
TOTAL MODEL	**0.11**

HAND-WRIST

No electronic performance monitoring variables remained in model.
Model variables same as in Table 11.

* Sum of partial R^2 do not typically equal total model R^2

FIGURE 1
OUTLINE OF STATISTICAL ANALYSIS
HETA 89-299, U.S. WEST COMMUNICATIONS

	Outcome = Case/Non-Case (Potential Work-Related Musculoskeletal Disorders)	Outcome = Ordinal (Musculoskeletal Symptoms)
	Univariate Analysis P<0.10	**Univariate Analysis** P<0.10
Step 1	A. Demographic B. Work Practices/Work Organization Individual Factors C. Psychosocial Factors D. Electronic Performance Monitoring (EPM) E. DAO Keystrokes Per Day (KPD) F. Denver DAO KPD	A. Demographic B. Work Practices/Work Organization Individual Factors C. Psychosocial Factors D. Electronic Performance Monitoring (EPM) E. DAO Keystrokes Per Day (KPD) F. Denver DAO KPD
	Multiple Logistic Regression P<0.05	**Multiple Linear Regression** P<0.05
Step 2	Separate Regression Models for A-F	Separate Regression Models for A-F
Step 3	One Regression Model for Variable A-C Surviving Step 2	One Regression Model for Variable A-C Surviving Step 2
Step 4a	One Regression Model for Variables A-C Surviving Step 3 Plus EPM (Variable D) Surviving Step 2	One Regression Model for Variables A-C Surviving Step 3 Plus EPM (Variable D) Surviving Step 2
Step 4b	One Regression Model for Variables A-C Surviving Step 3 Plus KPD (Variable E) Surviving Step 2	One Regression Model for Variables A-C Surviving Step 3 Plus KPD (Variable E) Surviving Step 2
Step 4c	One Regression Model for Variables A-C Surviving Step 3 Plus Den. KPD (Variable F) Surviving Step 2	One Regression Model for Variables A-C Surviving Step 3 Plus Den. KPD (Variable F) Surviving Step 2

APPENDIX A
PSYCHOSOCIAL VARIABLES
HETA 89-299, US West Communications

		Alpha Coeff*
1.	Control over job related matters	0.67
2.	Control over amount and quality of work	0.68
3.	Control over work policy and materials	0.55
4.	Participation in work decisions	0.89
5.	Skill utilization	0.67
6.	Cooperation between union and mgmt on health issues	0.68
7.	Job requires a variety of tasks	0.62
8.	Meaningful work	0.64
9.	Increasing work pressure	0.80
10.	Increasing workload	0.76
11.	Surges in workload	0.82
12.	Replaced by a computer	SS#
13.	Little interaction with others	SS
14.	Little interaction with co-workers	SS
15.	Lack of supervisor support	0.86
16.	Lack of co-worker support	0.77
17.	Uncertainty about job future	0.73
18.	Lack of friends and relatives (home) support	0.80
19.	Sum of supervisor, co-worker, and home support	0.80
20.	Boring work	0.82
21.	Work requires high mental demands	0.83
22.	High information processing demands	0.58
23.	Work requires very little thinking	0.61
24.	Sum of workload mental demands	0.79
25.	Customer hostility	SS
26.	Presence of a productivity standard	SS
27.	Computer monitors quantity	SS
28.	Computer monitors quality	SS
29.	Job Satisfaction	SV@

* Alpha coeff. = Chronbach alpha coefficients[36]

SS = Single scale

@ SV = Standardized value, see Methods section in text

APPENDIX B
ELECTRONIC PERFORMANCE MONITORING VARIABLES
HETA 89-299, US West Communications

	Alpha Coeff*
1. Fair productivity standard	SS#
2. Control and accuracy of computer monitoring	0.59
3. Monitoring rarely helps work performance and motivation	0.82
4. Monitoring invades the social aspects of the job	0.77
5. Monitoring results in more work	0.73
6. Monitoring results in negative feedback from supervisor	0.72
7. Most recent evaluation on work quantity	SS
8. Most recent evaluation on work quality	SS
9. Difficulty meeting productivity standard	SS
10. Computer closely monitors work quantity	0.20
11. Computer closely monitors work quality	0.36

* Alpha coeff. = Chronbach alpha coefficients[36]
# SS = Single scale

TABLE C-1
PHYSICAL WORKSTATION CHARACTERISTICS

HETA 89-299, US West Communications

Chair:

Arm Rests Present
Back Support Height Adjustable
Back Support Tension Adjustable
Back Support Tilt Adjustable
Seat Pan Tilt Adjustable
Seat Pan-Back Tilt Linked
Seat Pan-Back Tilt Link Mechanism
Seat Pan Height Adjustability
Seat Pan Height Mechanism (manual vs pneumatic)
Swivel/Coasters/Wheels
Pan Compression

Keyboard:

Key Configuration (Qwerty or Dvorak or Numeric)
Key Type [numeric vs mixed (alpha and numeric)]
Detachable
Separate Table
Sharp Edges
Wrist Support (Wrist Rests or Support)
Lateral Adjustment
Front-Back Adjustment
Height Adjustment
Height Adjustment Mechanism
Tilt Adjustment
Tilt Adjustment Mechanism
Mouse

TABLE C-1 (cont.)
PHYSICAL WORKSTATION CHARACTERISTICS

HETA 89-299, US West Communications

Screen:
- Position (Side or Center)
- Separate Table
- Lateral Adjustment
- Front-Back Adjustment
- Height Adjustment
- Height Adjustment Mechanism
- Tilt Adjustment
- Tilt Adjustment Mechanism

Document:
- Present
- Position (Side or Center)
- Lateral Adjustment
- Front-Back Adjustment
- Height Adjustment

Table:
- Sharp Edges
- Knee Envelop Adequate

Accessories: Foot Rest

TABLE C-2
PHYSICAL WORKSTATION CHARACTERISTICS - POSTURAL VARIABLES

HETA 89-299, US West Communications

Height and Distance Measurements:

Screen:	Floor to the center of the monitor's screen.
Document:	Floor to the center of the document.
Table:	Floor to the top of the table surface.
Keyboard:	Floor to the home row keys.
Chair:	Floor to the top of the seat pan.
Arm Rest:	Floor to the highest point on the arm rest.
Eye:	Floor to the fold at the corner of the eye.
Elbow:	Floor to the olecranon while typing on the keyboard (Height A, Figure 1).
Popliteal height:	Floor to popliteal area under thigh (Height J, Figure 1).
Pan Compression:	Compression of the chair seat pan padding.

Eye to Screen Distance: Front of the cornea to center of the screen.

Elbow to Keyboard Discrepancy: Keyboard height minus the resting elbow height.

Angle Measurements:

Wrist Ulnar Deviation: One arm of the goniometer placed over the third metacarpal; the other arm was positioned over the midline of the forearm with the axis approximately over the capitate (Angle D, Figure C-1).

Wrist Extension: Goniometer arms adjusted to be contiguous with the dorsal surfaces of the hand (along the third metacarpal) and forearm (Angle C, Figure C-1).

Shoulder Flexion: Angle between the humerus and the vertical plane (Angle G, Figure C-1).

Elbow Flexion: Angle between the horizontal plane and the ulna (Angle H, Figure C-1).

Inner Elbow Angle: Angle between the bicep and forearm (Angle E, Figure C-1).

Eye Gaze: Gaze angle from the eye to the middle of the VDT screen with respect to the horizontal (Angle I, Figure C-1).

Head Tilt to VDT: Difference between the angle formed by the Frankfort plane and the horizon while looking straight ahead (eye landmarks were the tragon of the ear and the external canthus of the eye) (Angle B, Figure C-2), and the angle formed by the Frankfort plane and the horizon while looking at the display (Angle A, Figure C-2).

TABLE C-3
Physical Workstations Characteristics - Chair
HETA 89-299, US West Communications

STATIC VARIABLES	**Overall**
Chair:	
Arm Rests Present	69%
Back Support Height Adjustable	31%
Back Support Tension Adjustable	68%
Back Support Tilt Adjustable	50%
Seat Pan Tilt Adjustable	68%
Seat Pan-Back Tilt Linked	95%
Seat Pan-Back Tilt Link Locking	44%
Seat Pan Height Adjustability	99%
Seat Pan Height Mechanism (manual vs pneumatic)	75% pneumatic
Swivel/Coasters/Wheels	100%

TABLE C-4
Physical Workstation Characteristics - Keyboard
HETA 89-299, US West Communications

STATIC VARIABLES	**Overall**
Keyboard:	
Key Configuration (Qwerty or Dvorak or Numeric)	Q=58%, D=40%, N=3%*
Key Type [numeric vs mixed (alpha and numeric)]	96% mixed
Detachable	100%
Separate Table	82%
Sharp Edges	20%
Wrist Support (Wrist Rests or Support)	35%
Lateral Adjustment	97%
Front-Back Adjustment	83%
Height Adjustment	78%
Height Adjustment Mechanism (power assist)	16%
Tilt Adjustment	90%
Tilt Adjustment Mechanism (power assist)	14%
Mouse	4%

* Percentages do not add up to 100% due to rounding errors

TABLE C-5
Physical Workstations Characteristics - Screen
HETA 89-299, US West Communications

STATIC VARIABLES	Overall
Screen:	
Position (Side or Center)	95% center
Separate Table	66%
Lateral Adjustment	60%
Front-Back Adjustment	72%
Height Adjustment	52%
Height Adjustment Mechanism (power assist)	24%
Tilt Adjustment	95%
Tilt Adjustment Mechanism (power assist)	0%

TABLE C-6
Physical Workstation Characteristics - Postural Variables
HETA 89-299, US West Communications

	Mean
Height and Distance Measurements:	
Screen height	40.4"
Document height	30.3"
Table height	28.0"
Keyboard height	28.9"
Chair height	18.8"
Arm rest height	26.7"
Eye height	44.6"
Elbow height	26.6"
Popliteal height	16.9"
Pan compression	0.8"
Eye to screen distance	26.8"
Elbow to keyboard discrepancy	<0.1"
Angle Measurements:	
Wrist ulnar deviation	174°
Wrist extension	152°
Shoulder flexion	29°
Elbow flexion	10°
Inner elbow angle	109°
Eye gaze	12°
Head tilt	6°

Figure C-1 (Appendix C)
Posture Measurements
HETA 89-299, US West Communications

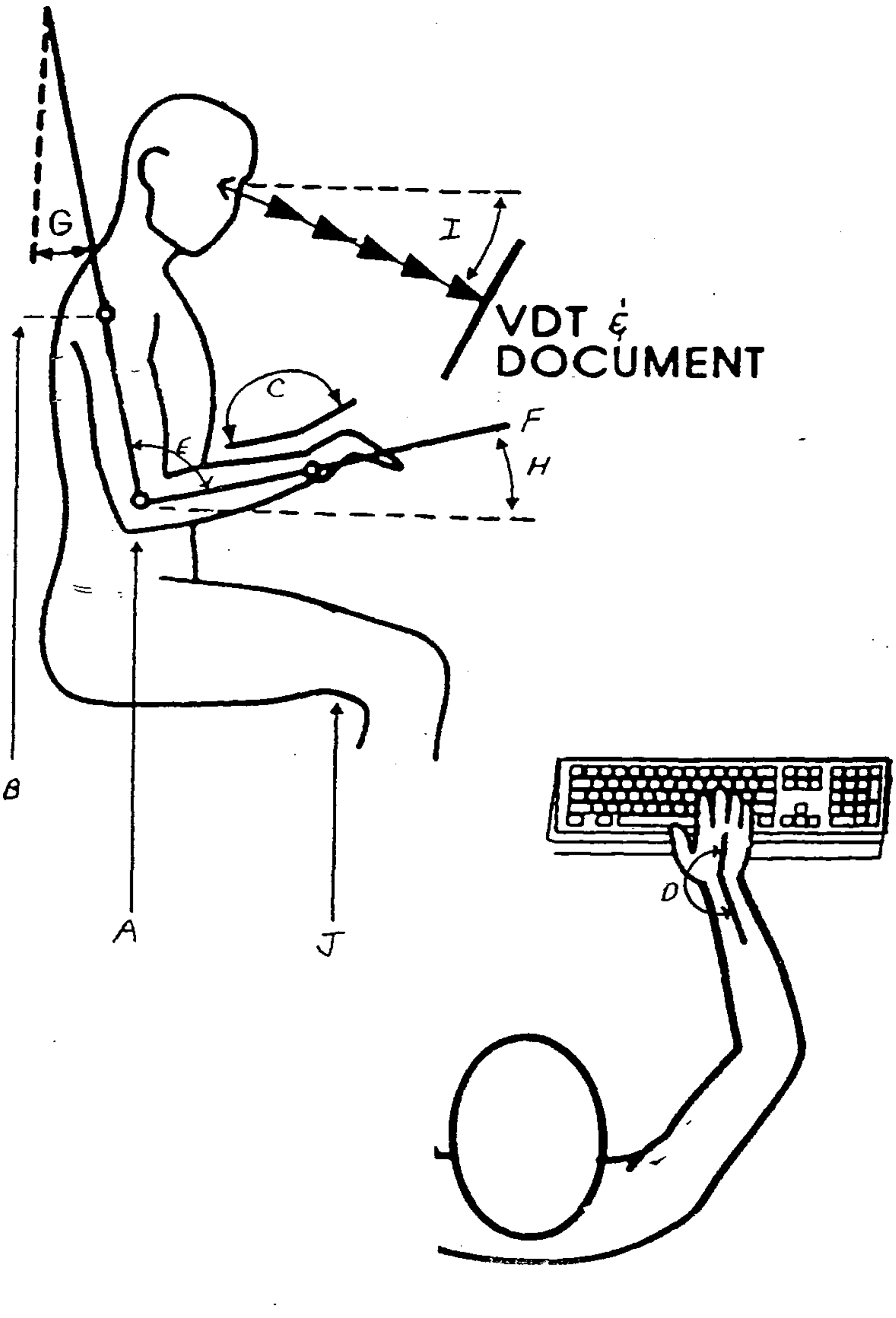

Figure C-2 (Appendix C)
Posture Measurements
HETA 89-299, US West Communications