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HEAT STRAIN ASSESSMENT STRATEGY. P. Dessureault, University of Quebec, Trois-Rivieres, Quebec, Canada

Two indices are extensively used in heat stress assessment programs. The first one, wet bulb and globe temperature (WBGT) is empirical, and the second, required sweat rate (RSR), is analytical. In both cases, a heat strain prediction, in terms of rise in core temperature (WBGT and RSR) or sweat lost (RSR) is made. Surprisingly, the cardiac strain is by far the reason most often reported to limit the duration of heat stress experiments under various climatic conditions. Today, instrumental improvements have made heart rate monitoring more convenient and accurate than many heat stress parameters.

The proposed strategy used the WBGT index to identify those workplaces to be studied. Thereafter, the RSR index (ISO 7933) is used to estimate the rise in core temperature and the sweat loss and when applicable, to determine an initial allowable exposure time. In the workplace, heart pulse is recorded on some workers for a full exposure period. Maximum and mean heart rates, recovery (Brouha), and percent of maximum heart rate range are analyzed and compared to well-documented criteria.

Observations were made under conditions covering a great variety of temperatures, humidity, clothing insulations, imperviousness, and metabolism. In nearly all cases where WBGT was exceeded and/or RSR gives a duration limited exposure, values in excess of one or more of the chosen heart strain criteria were recorded well earlier in the day. On 12-hour shifts, sweat loss can be the limiting factor. Rises in core temperature of 1 degree C or more were only observed under laboratory experiments during which heart rate values reached 85% and more of the maximum. In addition to the two heat stress indices and the heart rate monitoring, an education program completes the heat stress assessment strategy.

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COMPARISON OF INDIVIDUAL AND GROUP OBSERVATIONAL RATINGS OF ERGONOMIC STRESSORS. W.A. Latko, T.J. Armstrong, University of Michigan Center for Ergonomics, Ann Arbor, MI

Several physical stressors encountered in work tasks (e.g. repeated, sustained, and forceful exertions, contact stresses, awkward postures, highly dynamic movements, insufficient recovery time, low temperatures, and vibration) have been linked to increased risk of musculoskeletal disorders. An observational rating system consisting of fifty-two 10 cm visual-analog scales corresponding to the different stressors and segments of the upper limb has been developed to quantify exposure to these stressors. The system makes use of a series of decision rules and benchmark examples to aid in determining the magnitude of each stressor. Four teams of raters (3-5 members per team, 17 total) were trained in the method and rated the same 12 manufacturing jobs. Each team member rated all job parameters individually, then each team discussed their ratings with the goal of reaching consensus (defined as a range of no more than 1 point). Among the 17 raters, initial individual ratings were in agreement (± 0.5 point) approximately 25% of the time for a given job and stressor. When the range defining agreement is increased to ± 1.5 points, the percentage of raters in initial agreement rises to 64%-90%. All groups were able to reach consensus on all scales; inter-group variability was usually less than 2 points. This rating method can be useful to teams of health and safety professionals or plant-based ergonomics teams for quantifying exposure to physical stressors. When used with the team consensus process, it can be used to classify exposure into approximately 5 levels. Individual analysts can also use the method; however, there is an increase in variability. The ratings obtained from this method are useful for prioritizing jobs for intervention, assessing the impact of interventions, and providing exposure data for epidemiological studies.

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WORK FACTORS ASSOCIATED WITH MUSCULOSKELETAL DISORDERS IN POWER DISTRIBUTION JOBS. R. Marley, A. Gebhardt, L. Lavier, Montana State University, Bozeman, MT; R. Nicholls, Montana Power Co., Butte, MT

The incidence of musculoskeletal disorders (MSDs) has increased dramatically in recent years and has become a key concern for occupational safety and health care professionals. Several factors such as repetition, forceful exertion, and awkward postures, have been linked to the development of work-related MSDs. While these links have been well established, valid and reliable evaluation techniques for MSD risk are lacking, particularly for jobs in nonmanufacturing industries or otherwise classified as nonrepetitive. This study examined such jobs in the power distribution industry with a goal of better understanding which work factors may be associated with MSDs. Injury data from over 2000 workers in one company were tabulated by job classification (12 total classes). Pareto analysis revealed that the rate of MSDs was highest for electric line crews (6.2/100 FTE), lowest for meter readers (1.7/100 FTE) and nearly between were gas line crews (2.9/100 FTE). An ergonomic/work-methods analysis was then performed on five key activities within these jobs. Activities were further broken down into 74 required tasks (e.g., climb pole, make connection, shovel, cut pipe, etc.) and then into 15 fundamental work elements (e.g., various body postures, grasp type, force level, duration, terrain condition, etc.). The fundamental work elements were quantified into 42 levels which represented the variables for further analysis. Cluster analysis was performed to determine natural groupings of variables and simplify the data structure. This procedure resulted in 10 clusters and a discriminant function was then derived based on composite scores (from variables in each cluster). The discriminant function was significant [$F(20,108)=14.04$, $p<0.0001$) with respect to its ability to correctly identify, with 83% accuracy, the job class and associated level of MSD risk via knowledge of specific factors. Not surprisingly, smaller deviations in posture and lower force requirements were associated with the lowest level of MSD risk. Finally, a score sheet has been developed based on cluster scores which can be used to conduct preliminary MSD risk evaluation or to perform "what if" analysis in job redesign considerations. This may provide insight into similar jobs or trades where work activities vary widely.

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ERGONOMIC AND EPIDEMIOLOGIC EVALUATION OF A BIOLOGICAL LABORATORY. J. McGlothlin, T. Hales, NIOSH, Cincinnati, OH

Laboratory technicians who work in biosafety cabinets and use pipettes are at risk for developing musculoskeletal injuries and illnesses. Recently, NIOSH researchers conducted an evalutation at a federal research laboratory because of increased reports of cumulative trauma disorders (CTDs) among research technicians working in the anticancer drug screening labs commonly known as the production laboratories. NIOSH investigators made an initial visit to the facility and conducted an ergonomic and medical evaluation; then, approximately 1 year later, conducted a follow-up study to evaluate changes in job risk factors and musculoskeletal morbidity rates. The medical evaluation consisted of a record review of OSHA Form 200, workers' compensation claims (WCC), and individual medical records maintained by the on-site occupational health clinic. For employees of the production labs, informal confidential medical interviews were conducted, and a questionnaire was administered. The ergonomic evaluation consisted of a walk-through survey, informal interviews of production lab employees, and videotaping and analyzing job risk factors of production lab employees. Interim administrative and engineering recommendations to reduce job stressors were provided at the close of the first visit. Although the production lab employees represented less than 5% of the entire federal contractor work force, they represented 19 (26%) of the recordable CTD cases, 440 (80%) of the lost workdays, and 765 (56%) of the restricted workdays. In 1995, the number of production lab cases was reduced to three cases with no lost restricted workdays. Ergonomic job analysis of the production labs revealed that the production employees performed approximately 6000 to 11,700 repetitive motions per day involving the pipette. In addition, employees assumed awkward and static posture of the hand and thumb while activating the pipette plunger, and while extending the arm inside the biosafety cabinet to perform the pipetting operations. These repetitive motions in awkward and static postures during the pipetting tasks put employees at risk for developing CTDs. In 1995, several administrative and engineering controls were implemented to reduce employee CTD exposure. Administrative controls included more efficient drug screening protocols which allowed a 30% reduction in laboratory pipetting operations. In addition, more work breaks (5 to 15 minutes) were scheduled during pipetting operations, and all laboratory

employees were encouraged not to rush through the pipetting tasks. Engineering controls such as foot-activated pipette liquid dispensers to reduce hand fatigue, and a robot to substitute manual pipetting operations, were also implemented. These administrative and engineering controls may have, in part, resulted in the reduction in the number and severity of OSHA 200 Log CTD cases experienced by the production labs in 1995.

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EFFECTS OF LONG TERM AUDITORY FEEDBACK ON FORCE, EMG, PERCEIVED EXERTION, AND COMFORT WHILE TYPING. M.J. Gerard, T.J. Armstrong, C.B. Woolley, University of Michigan, Center for Ergonomics, Ann Arbor, MI

The goal of this work was determine the long term effects of auditory feedback on reducing the keyboard reaction force produced while typing. Ten female typists participated in the study. Each subject's keyboard (key activation force of 0.71 N) was equipped with an external feedback device which produced auditory tones based on keyboard reaction force. Headphones were connected to the feedback device and worn for the first hour each morning. The subjects were instructed to use the auditory feedback to reduce their typing force. After the first hour subjects removed their headphones and continued working. The subjects used the feedback device with the keyboard at their workstation for approximately ten work days. Once a week subjects participated in a controlled typing test where typing speed was held constant while typing. Subjects typed for ten minutes without feedback during which time keyboard reaction force and surface EMG of the finger flexors and finger extensors for the left hand were monitored. The subjects then typed for ten minutes with auditory feedback and were monitored. When feedback was introduced 90th percentile APD keyboard reaction force decreased 20% from 2.50 N to 2.00 N. 90th percentile finger flexor EMG decreased from 18% MVC to 14.7% MVC. 90th percentile finger extensor EMG decreased from 19.18% MVC to 16.5% MVC. After one week of receiving auditory feedback for one hour a day 90th percentile keyboard reaction force while not receiving auditory feedback decreased from 2.50 N to 2.07 N. There were no accompanying changes in finger flexor or finger extensor EMG. The above results suggest that auditory feedback can reduce keyboard reaction force and EMG while typing. After using auditory feedback one hour per day for one week keyboard reaction force while typing remained lower even after the feedback was removed.

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WRIST AND FOREARM POSTURE OF TYPISTS USING ALTERNATIVE KEYBOARDS. R. Marklin, G. Simoneau, J. Monroe, Marquette University, Milwaukee, WI

Hand and wrist cumulative trauma disorders (CTDs), such as carpal tunnel syndrome, have been troublesome in the clerical service sector in the U.S., which has an employment base of over 18,000,000 (Stat. Abstract of the U.S., 1992). Many clerical workers exert 50,000 to 100,000 key strokes per day. While the exact cause of occupationally induced CTDs in computer keyboard users is not known, the deviated wrist posture and forearm posture (ulnar deviation and pronation, respectively) dictated by the design of the conventional, flat keyboard is often implicated in the etiology of hand and wrist CTDs. In response to this problem, several new alternative keyboard designs have entered the market. However, little quantitative data are available as to whether the fundamental designs of these keyboards actually reduce deviated wrist and forearm posture.

The specific aim of this NOSH-sponsored study is to determine whether the fundamental designs of alternative keyboards have a beneficial effect on the posture of the wrist and forearm, i.e., whether alternative keyboards impose less ulnar deviation and forearm pronation on the data entry operator than the conventional, flat keyboard. Ninety experienced clerical personnel practiced typing for at least 20 hours in their respective workplaces on one of three fundamental designs commercially available keyboards: fixed-angle split, adjustable-angle split, and vertically inclined. Each subject's wrist and forearm motions were monitored in the laboratory with electrogoniometry while he or she was typing. Results show that the conventional keyboard required 10 degrees of ulnar deviation, while the fixed-angle and adjustable angle keyboards eliminated ulnar deviation and maintained the wrist in a neutral posture. The vertically inclined keyboard reduced the pronation of the forearm by 20 deg. (from 60 deg. for a conventional keyboard to 40 deg. for the vertically inclined). The overall results show that the split and vertically inclined keyboards achieve what their manufacturers claim, i.e., that these alternative keyboards place the wrist or forearm in a more neutral posture for typing.

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AN ERGONOMIC ASSESSMENT OF TWO INDUSTRIAL SPRAY PAINT GUNS. W.S. Marras, K.G. Davis, C.C. Lee, J.E. Nelson, Ohio State University, Columbus, OH

Cumulative trauma disorders (CTDs) can result from repeated and forceful exertions that occur with the hand in sustained deviated postures. Industrial spray painting tasks represent an environment where these risk factors are present. This study quantitatively evaluated the potential benefits of a prototype ergonomic spray paint gun compared to a traditional industrial spray paint gun. The ergonomic gun's features included reduced gun and hose weight and two triggers (one for horizontal surfaces and one for vertical surfaces). Five experienced and five inexperienced painters performed a typical industrial spray painting task for four hours. The criteria used to evaluate the two guns were: 1) wrist deviations in all three axes, 2) EMG median frequency shifts of three shoulder muscles over the test period, 3) forearm muscle activity (via EMG), and 4) body discomfort rating. The prototype gun resulted in significantly less radial/ulnar wrist deviation, with moderate increases in wrist flexion/extension and supination/pronation deviations from neutral. Up to 50% less fatigue was also observed in the shoulder muscles when the prototype gun was used. Additionally, the triggering activation levels for sustained grip contractions were found to be more acceptable for the ergonomic gun when using a short trigger. Finally, the amount of discomfort reported by the subjects was statistically lower in the shoulder, upper back, arm, elbow, forearm, wrist, and hand with the ergonomic gun design. Collectively, these results indicate that the ergonomic gun would be expected to reduce exposure to occupational risk factors for workers. This study demonstrates that ergonomic design of tools does play an important role in minimizing occupationally-related risk. of CTDs.

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THE DEVELOPMENT OF A BIOMECHANICAL MODEL OF THE LOW BACK FOR EVALUATING MATERIALS HANDLING DEVICES. D. Chaffin, University of Michigan, Ann Arbor, MI; M. Nussbaum, Virginia Polytechnical and State University, Blacksburg, VA; C. Sowden, Ford Motor Co., Redford, MI

As many manual materials tasks have become recognized as hazardous to workers, a greater variety of mechanized materials handling devices (MHDs) have been developed and aggressively marketed. Unfortunately, the complexity of most manual materials handling operations often results in MHDs that are not well designed to reduce often dynamic low back stresses. The objective of this project was to develop a biomechanical model of a person's torso which could be used to evaluate the specific dynamic spinal loads imposed by various MHDs. The development process involved the following: (1) existing biomechanical torso models were reviewed to determine their suitability to assess the dynamic torso loads imposed when lifting, pushing, and pulling various MHDs; (2) a torso geometric model was created which could be scaled to the anthropometric characteristics of a person using an MHD; (3) software was written to allow for fully 3D dynamic analysis of unconstrained exertions; and (4) an MHD laboratory was created wherein volunteers could be studied while dynamically lifting, pushing, and pulling different types of MHDs. The laboratory allowed the automated measurement of hand forces, 3D dynamic postures, and 12 channels of torso muscle EMGs. The results of these activities indicate that torso muscle coactivation exists when stopping and starting MHD motions. This appears to be due to the propensity of people to impart relatively high peak hand forces due to the inertia of the MHD and load combination. Peak low back moments combine with torso muscle antagonism to produce spinal rotation segment forces which are sufficient in some situations to raise questions about the safe designs of certain types of MHDs in specific materials handling situations. In particular, lateral MHD twisting movements with high loads and fast-paced motions are shown to cause

1997
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Co-sponsored by American Industrial Hygiene Association and American Conference of Governmental Industrial Hygienists