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

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