DIRECT MEASUREMENT OF EXPOSURES TO THE UPPER EXTREMITY DURING AUTOMOBILE MANUFACTURING

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This paper explores the measurement of wrist posture and motion on workers in two jobs at a plant that stamps sheet metal parts to be used in automobile assembly. It was hypothesized that the welding assemblers would have more wrist motion than the large press operators, who performed primarily manual material handling activities. Wrist posture was ascertained using a biaxial flexible wire electrogoniometer. Numerical differentiation was performed to calculate angular velocity and acceleration from the posture data. No significant differences were found for the wrist posture or motion data between the jobs.

INTRODUCTION

Direct measurements of exposures to the upper extremity have been made using electrogoniometry and electromyography. The broad objective of this research is to validate a questionnaire that has been used to collect subjective self-reports of exposure. This paper explores the measurement of wrist posture and motion on workers in two jobs at a plant that stamps sheet metal parts to be used in automobile assembly.

Analysis of posture data varies from the calculation of simple summary statistics (mean, maximum, minimum) to more complex analyses. A commonly used method for analyzing posture data determines the percentage of time spent in various posture categories (e.g. Armstrong *et al.* 1982, Keyserling, 1986, Punnett *et al.* 1991). With the increasing use of electrogoniometers in exposure studies, the velocity and acceleration of body segment motions can be determined. Accelerations and velocities of the trunk are thought to be predictive of the risk of low-back pain (Marras *et al.* 1993; Marras *et al.* 1995) and therefore may be predictive of a worker's subjective assessment of the awkwardness of the back posture. Acceleration and velocity are also thought to be important factors in the development of hand and wrist musculoskeletal disorders (Marras and Schoenmarklin, 1993).

METHODS

Subjects for this study were selected from a larger survey of musculoskeletal disorders. In all there were 75 subjects on which direct measurements of shoulder posture, wrist posture and grip force were made using electrogoniometry and electromyography. For this analysis of wrist posture and motion, six of these subjects were selected. Three of the workers were large press operators, who "racked" large parts (e.g. hoods and doors) at the end of the press line. The other three workers were welding assemblers, who fed small sheet metal pieces to the welding machine during the assembly of larger parts (e.g. hoods and doors). The hypothesis was that the welding assemblers would have more wrist motion than the large press operators, who performed primarily manual material handling activities.

Wrist posture was ascertained using a biaxial flexible wire electrogoniometer (Penny and Giles Blackwood Ltd., Gwent, UK). The goniometer has been used in a number of studies of the wrist joint, e.g. Smutz *et al* (1994) employed the goniometer for wrist posture measurement in their ergonomic assessment of keyboard designs; Moore *et al* (1991) and Wells *et al* (1994) used the goniometer to quantify wrist motion/posture in their field assessments of ergonomic risk factors; and Ojima *et al* (1991) performed a dynamic analysis of wrist circumduction using the goniometer in clinical trials. The Penny and Giles goniometer has been shown to be an effective device for quantifying joint postures and motions, but when measuring flexion/extension and radial/ulnar deviation of the wrist, there is cross-talk between the channels associated with forearm rotation (Armstrong *et al*, 1993; Buchholz and Wellman, 1997; Moore *et al*, 1991). The errors due to cross-talk may be minimized with careful selection and placement of the goniometer (Buchholz and Wellman, 1997; Wells *et al*, 1994) and/or corrected for by using an algorithm developed for this purpose (Buchholz and Wellman, 1997; Casolo and Legnani, 1990). In this study a goniometer with a shorter wire was selected.

Goniometer data (4 channels) were stored on a data logger (Tattletale Model 5F, Onset Computer Corp.) along with inclinometer data (2 channels) and electromyographic data (2 channels) at 60 Hz to allow numerical differentiation. The data logger had ½-mega byte of memory, which allowed approximately 9 minutes of data collections per subject.

For each subject, the middle 5 minutes of data were used in the analysis. The mean posture for each plane of motion was calculated along with the maximum posture in each direction of motion. These were averaged across subjects for the two jobs. Posture data were smoothed prior to numerical differentiation to velocity and the calculated velocity data were smoothed prior to differentiation to acceleration. Maximum velocity and acceleration was determined for each direction of motion and mean velocity and acceleration were calculated using absolute values. All of these were averaged across subjects for the two jobs.

RESULTS

The comparisons of wrist posture and motion between the large press operators and the welding assemblers are shown in Table 1 (wrist posture), Table 2 (wrist velocity) and Table 3 (wrist acceleration). None of the differences between jobs was statistically significant.

Table 1. Wrist posture (degrees) comparison.

	Flexion/Extension			Radial/Ulnar Deviation		
Job	max flex	max ext	mean*	max uln	max rad	mean*
large press operators	36.8	-42.8	-10.8	21.9	-34.1	-2.1
welding assemblers	45.2	-56.9	-10.6	27.9	-29.6	-0.2

* The negative signs indicate extension and radial deviation.

Table 2. Wrist velocity (degrees/second) comparison.

	Flexion/Extension			Radial/Ulnar Deviation		
Job	max flex	max ext	mean*	max uln	max rad	mean*
large press operators	212.6	-219.9	17.4	157.1	-145.9	14.1
welding assemblers	334.1	-218.0	21.0	143.1	-156.7	11.9

* For velocity, the mean of the absolute values was used.

Table 3. Wrist acceleration (degrees/second^2) comparison.

	Flexion/Extension			Radial/Ulnar Deviation		
Job	max flex	max ext	mean*	max uln	max rad	mean*
large press operators	1331.9	-1591.5	121.7	1300.0	-1131.6	99.5
welding assemblers	2040.8	-2497.2	147.9	1246.9	-1336.1	84.0

* For acceleration, the mean of the absolute values was used.

DISCUSSION

It was somewhat surprising that there were no significant differences in wrist postures or motions between the large press operators and welding assemblers. On observation, the operators performed a manual material handling task and one would not expect a lot of wrist motion, although they did need to manipulate the parts as they were taken off the press line and placed in the parts rack. Conversely, the assemblers performed a task comprised almost entirely of hand work, with associated motion of the entire upper extremity and it was expected that they would use considerable wrist motion. The cycle time on the welding machines were approximately 20 seconds and the motions required to place a part and press a palm button were not extreme.

The motions in these two jobs are considerably less when compared with the jobs measured by Marras and Schoenmarklin (1993). The velocities they measured for both high- and low-risk groups were nearly double those measured here and accelerations were more than triple.

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