A Prospective Study for Upper-Extremity Cumulative Trauma Disorders of Workers in Aircraft Manufacturing

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Occupational diseases affect 15 to 20% of all Americans. Cumulative trauma disorders (CTDs) account for 56% of all occupational injuries. The recognition and control of occupational injuries has become a major concern of employees, employers, medicine, and the federal government because of health risk and related costs. Upper-extremity CTDs are identified by the National Institute for Occupational Safety and Health as one of the ten most significant occupational health problems in the United States. It is estimated by the year 2000 that 50 cents on the dollar will be spent on CTDs. Although enlightened aircraft employers have developed primary prevention strategies, primary prevention can never be expected to eliminate 100% of the cases. To evaluate several preventive activities, a CTD risk-assessment program was developed and implemented in cooperation with a major aircraft manufacturer employing over 8000 workers. This program was focused on objectively identifying the relationship of work and other activities to an individual worker experiencing CTDs. Early identification has been linked, when applicable, to intervention algorithms for medical care, job task modification, workplace accommodation, and training. A prospective study group of 212 workers who used rivet guns was placed into a four-way experimental design for ergonomic posture training, exercise training, and rivet-gun type (primary factors). A statistical model was developed for the level of CTD risk and evaluated using the SAS software program (SAS Institute, Inc., Cary, NC). Statistical analysis of the primary factors without regard to associated variables (covariates) demonstrated that only posture training had a beneficial risk reduction for the individual. The impact (beneficial or detrimental) for exercise training and for vibration-dampening rivet guns was probably obscured because of the large variability of the responses regarding the associated variables (covariates). When the covariates were analyzed in conjunction with the four experimental groups, a positive benefit from ergonomic posture training and exercise training was demonstrated for the following groups: the dominant hand, time spend in an awkward position, number of standard rivets bucked, number of parts routed, number of parts ground, number of vibration-dampening rivets bucked, and newly hired individuals. A negative effect (increase in individual risk level) for current employees using a vibration-dampening rivet gun was demonstrated. This prospective study helps to identify the possible benefit of education and training for controlling CTDs and demonstrates the usefulness of being able to evaluate materials, methods, machines, and environments as they relate to the individual's risk level for the development of upper-extremity CTDs.

Upper-extremity cumulative trauma disorders (UECTDs) are identified by the National Institute for Occupational Safety and Health as one of the ten most significant occupational health problems in the United States, accounting for 56% of all occupational injuries that affect 15 to 20% of all Americans.[1,2] The recognition and control of occupational injuries has resulted in the growing need for prospective studies on the etiology and prevention of UECTDs. Most studies of UECTDs have been based on the people, materials, methods, machines, and environment model. Although some guides have been developed for the materials, methods, machines, and environment, the people component has defied specific measurement. The lack of instruments to measure the individual's risk for development of UECTDs, based on age, gender, genetics, workplace, non-work environment, and linked elements, has limited the design of prospective studies.[3-6]

This study was designed as an experimental model to determine the impact of ergonomic posture training, exercise training, and rivet-gun type as they related to decreasing the risk to the individual for developing UECTDs. Because of the multiple factors in the workplace, additional associated variables (covariates) were studied for each of the primary factors. These covariates were then compared with the primary factors for their impact on the reduction of risk for the individual.

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1076-2752/96/3812-1264$3.00/0

Methods and Materials

Members of a random sampling of 212 workers from a major aircraft industry's work force of 8000 were randomly assigned to the one of four primary factor groups: ergonomic posture training, exercise training, rivet-gun type, and a control. The study group consisted of 158 men and 54 women. Their ages ranged from 22 to 59, with an average of 44 years. Dominant hand preference was 92.5% right and 7.5% left. None of the individuals had a history of previous UECTDs or had received medical treatment for UECTDs.

During the 15-month study, the individual risk levels were established by monitoring assessment (clinical screening). This screening included a questionnaire, limited physical measurements, and noninvasive nerve sensitivity testing. Statistical analysis was then used on the data obtained from the monitoring assessment program (MAP) to provide the individual's risk level, on a scale of one to seven, for the probability of developing UECTDs. The monitoring was completed before the assignment to groups and repeated at 7 and at 15 months. The risk scale for each individual was used to evaluate the benefits of the primary factors and to analyze the impact of the covariates on the primary factors for the reduction of UECTDs. During the study, four individuals were switched between the vibration-dampening rivet gun and the standard rivet gun to assist with the statistical analysis and with improved sensitivity and specificity of the data. Sample size was determined in advance by statistical modeling to require a minimum study group of 16 or more individuals for each of the eight study groups. This was based on the employer's providing monitors that would check on individual compliance with the study protocols and removing any individual who had a job transfer or end of employment. Eight individuals were transferred to different jobs and were not included in the study. An additional 11 were lost from the study because of lay-offs or loss of employment.

The ergonomics posture training included awareness of early warning signs of UECTDs, methods for controlling risk factors, techniques to apply forces with less stress or strain, and correct posture and stance to improve balance and apply or absorb forces.

The exercise training included methods to relax muscles in the shoulders, arms, and back; to stretch muscles and tendons in the shoulders, forearms, wrists, and hands gently; and to increase circulation in the arms and hands.

The vibration dampening rivet gun group had training and practice using the vibration-dampening (recoilless) rivet gun and tools before starting on actual production work. The tools were used with conventional bucking bars and not with the recently developed reduced-vibration bucking bars.

The standard rivet gun group had training and practice using the standard rivet gun and tools before starting on actual production work. The tools were used with conventional bucking bars and not with the recently developed reduced-vibration bucking bars.

At the completion of the study, the groups were compared for changes in the level of risk assigned. There were 193 of the original 212 individuals available for review. The change in risk level was computed as the original risk level minus the risk level when evaluated at the end of the study. A negative score meant that the individual's risk of UECTDs had decreased, and a positive score meant that the risk of UECTDs had increased. An analysis for interactions with each of the three primary factors effects was done with SAS statistical software.[7]

The model tested was:

$$\begin{aligned} Fijklmn = \mu &+ Ai + Gj + Xk + Pl \\ &+ AGij + AXik + APil + GXjk \\ &+ GPjl + XPkl + AGXijk \\ &+ AGPijl + GXPjkl + AGXPijkl \\ &+ Wijklm + Tn + Atin \\ &+ GTjn + XTkn + Ptin \\ &+ AGTijn + AXTikn + APTiln \\ &+ GXTjkn + GPTjln + XPTkln \\ &+ AGXTijkn + AGPTijln + \\ &GXPTjkln + AGXPTijkln + \epsilon ijklmn \end{aligned}$$

where Fijklmn is the level of UECTD risk, μ is the mean, Wijklm is the experimental error resulting from mechanics and assumed to be distributed i.i.d $N(0,\sigma w2)$, and $\epsilon ijklmn$ is the measurement error for a given 6-month period, which is assumed to be distributed as i.i.d $N(0,\sigma e2)$, with A = area, G = rivet gun, P = posture, T = time, and X = exercises.

Covariates were not controlled, but data was collected on them during the course of the study. The covariates were:

Stdhrs: Hours spent using a standard rivet gun.
Nrivstd: Number of rivets driven using a standard rivet gun.
Buckstd: Time spent bucking rivets driven with a standard gun.
Nrivbks: Number of rivets bucked that were driven with a standard gun.
Rechrs: Hours spent using a recoilless rivet gun.
Nrivrec: Number of rivets driven using a recoilless rivet gun.
Buckrec: Time spent bucking rivets driven with a recoilless gun.
Nrivbkr: Number of rivets bucked that were driven with recoilless gun.
Timeawk: Time spent working in an awkward position.
Timedril: Time spent drilling holes.
Nholes: Number of holes drilled.
Timecsk: Time spent countersinking holes.
Nholecsk: Number of holes countersunk.
Timegrin: Time spent grinding parts.
Npartsg: Number of parts ground.

TABLE 1
Control Group for Vibration-Dampening Rivet Guns*

Numb	R0	L0	R1	L1	R2	L2	EXER	ERGO	GUN	HAND	JOB	TEST
1648	3	3	2	2	3	3	N	N	R	R		test
2207	3	2	4	3	3	3	N	N	R	R		test
2740	2	3	2	3	2	5	N	N	R	L		
3605	3	6	5	5	5	6	N	N	R	R		
3682	4	4	3	3	2	2	N	N	R	R		
3762	3	3	3	3	3	2	N	N	R	R		
3959	2	2	2	1	3	1	N	N	R	R		
4320	4	3	3	4	2	3	N	N	R	R		
4441	3	2	3	2	4	4	N	N	R	R		
4841	5	3	5	3	5	4	N	N	R	R		
5039	5	3	3	4	3	3	N	N	R	R		
5091	2	3	3	2	1	2	N	N	R	R		
5679	4	4	2	2	3	3	N	N	R	R		
5940	2	3	2	3	2	3	N	N	R	R		
6025	3	6	3	7	5	2	N	N	R	R		
6329	5	3	4	3	2	2	N	N	R	R		
6554	3	3	2	2	2	2	N	N	R	R		
6600	4	4	5	4	5	4	N	N	R	R		
7231	4	5	4	4	4	5	N	N	R	R		
7297	4	4	NA	NA	NA	NA	N	N	R	R		
8175	3	2	NA	NA	NA	NA	N	N	R	R		
8331	3	2	4	3	3	3	N	N	R	R		
9036	4	5	4	5	5	4	N	N	R	R		
9571	2	2	2	3	2	3	N	N	R	R		
9736	3	5	5	4	2	2	N	N	R	L		
9786	3	3	2	3	3	3	N	N	R	L		

* Numb, individual assigned study number; R0 and L0, starting monitoring assessment program (MAP) risk levels; R, right; L, left; R1 and L1, intermediate MAP risk levels; R2 and L2, end MAP risk levels; EXER, exercise program; ERGO, ergonomic training program; GUN, rivet gun type used (S, standard rivet gun, and R, vibration-dampening rivet gun); JOB yes, individuals transferred during the study; TEST, individuals exchanged at the halfway study point to the other gun group; N, no; Y, yes; NA, data not available and individual not included in the final analysis.

TABLE 2
Control Group for Standard Rivet Guns*

Numb	R0	L0	R1	L1	R2	L2	EXER	ERGO	GUN	HAND	JOB	TEST
0061	2	3	3	3	2	2	N	N	S	L		
0105	7	6	7	6	7	6	N	N	S	R		
0310	2	2	2	1	3	3	N	N	S	R		test
0914	1	3	1	2	3	2	N	N	S	R		test
1360	5	1	4	1	4	3	N	N	S	R		
1559	3	3	3	3	2	3	N	N	S	R		
2615	2	2	1	1	2	4	N	N	S	R		
2645	4	5	4	4	5	5	N	N	S	R		
3916	3	4	4	3	4	2	N	N	S	R		
4190	3	2	3	3	3	3	N	N	S	R		
4725	2	3	2	3	3	3	N	N	S	R		
5259	4	3	4	3	1	2	N	N	S	R		
5285	4	5	4	4	5	3	N	N	S	R		
5747	5	7	4	4	5	4	N	N	S	R		
5931	4	2	NA	NA	NA	NA	N	N	S	R		
6006	4	5	4	3	5	3	N	N	S	R		
7059	3	2	3	2	3	2	N	N	S	R		
7289	2	5	2	5	NA	NA	N	N	S	L	yes	
7591	4	4	6	4	5	2	N	N	S	R		
8309	3	2	4	2	2	2	N	N	S	R		
8555	5	4	5	5	5	4	N	N	S	R		
8669	4	4	3	4	3	3	N	N	S	R		
8758	5	4	5	5	4	5	N	N	S	R		
9248	1	4	2	4	2	2	N	N	S	L		
9421	3	3	3	3	3	3	N	N	S	R		
9426	7	6	5	7	5	7	N	N	S	R		
9519	5	3	2	2	2	2	N	N	S	R		
9563	5	5	4	3	5	4	N	N	S	R		

* Abbreviations are defined in the footnote to Table 1.

TABLE 3
Exercise Program, No Ergonomic Training Program, Standard Rivet Guns*

Numb	R0	L0	R1	L1	R2	L2	EXER	ERGO	GUN	HAND	JOB
0441	2	2	2	2	2	2	Y	N	S	R	
0551	3	3	3	3	3	3	Y	N	S	R	
0565	4	2	2	3	2	2	Y	N	S	R	
0619	5	2	6	2	7	4	Y	N	S	R	
0712	6	6	NA	NA	NA	NA	Y	N	S	L	yes
0933	1	2	2	3	3	2	Y	N	S	R	
1176	3	2	2	2	3	2	Y	N	S	R	
1292	6	3	NA	NA	NA	NA	Y	N	S	R	yes
1651	2	2	4	3	3	2	Y	N	S	R	
1689	4	2	5	3	5	4	Y	N	S	R	
2070	3	3	5	3	4	3	Y	N	S	R	
2374	2	2	2	2	4	1	Y	N	S	R	
2584	3	3	3	3	3	3	Y	N	S	R	
2907	2	3	2	3	2	3	Y	N	S	R	
3136	3	4	3	4	3	4	Y	N	S	R	
3229	3	5	2	3	2	2	Y	N	S	R	
3405	5	6	7	5	5	3	Y	N	S	R	
3442	3	2	2	2	2	3	Y	N	S	R	
4459	4	4	4	3	2	3	Y	N	S	R	
5556	3	2	3	2	3	2	Y	N	S	R	
6144	5	3	4	4	2	2	Y	N	S	R	
7001	3	5	3	4	4	5	Y	N	S	R	
7886	2	5	1	3	2	5	Y	N	S	R	
8278	2	3	2	3	2	4	Y	N	S	R	
8940	4	3	4	4	4	5	Y	N	S	L	
9018	2	2	3	3	4	2	Y	N	S	R	

* Abbreviations are defined in the footnote to Table 1.

TABLE 4
Exercise Program, No Ergonomic Training Program, Vibration-Dampening Rivet Guns*

Numb	R0	L0	R1	L1	R2	L2	EXER	ERGO	GUN	HAND	JOB
0266	2	4	2	2	3	3	Y	N	R	R	
1216	3	7	4	6	4	6	Y	N	R	R	
1273	2	2	2	3	2	2	Y	N	R	R	
1446	2	5	3	5	3	5	Y	N	R	R	
1931	2	3	2	1	1	2	Y	N	R	R	
2863	2	3	2	2	2	3	Y	N	R	R	
3290	4	4	4	4	3	4	Y	N	R	R	
3464	4	4	3	2	3	3	Y	N	R	L	
3634	3	2	4	3	3	3	Y	N	R	R	
4329	1	1	2	3	1	2	Y	N	R	R	
5000	2	2	4	3	3	2	Y	N	R	R	
5017	3	4	3	4	3	3	Y	N	R	R	
5300	2	4	3	4	NA	NA	Y	N	R	R	yes
6286	3	3	3	2	3	2	Y	N	R	R	
6339	2	3	1	3	3	1	Y	N	R	L	
6620	3	2	3	4	4	3	Y	N	R	R	
6667	4	2	3	2	3	3	Y	N	R	R	
7246	5	5	4	4	4	4	Y	N	R	R	
7607	2	3	3	2	3	2	Y	N	R	R	
7663	3	4	5	5	5	4	Y	N	R	R	
7800	5	3	5	3	3	2	Y	N	R	R	
7834	3	2	3	2	3	2	Y	N	R	R	
7956	4	4	4	3	4	3	Y	N	R	R	
8124	4	2	4	5	4	4	Y	N	R	R	
8762	2	3	2	3	2	3	Y	N	R	L	
8924	2	3	1	3	2	2	Y	N	R	R	
9424	3	2	3	2	4	4	Y	N	R	R	
9921	3	2	1	2	4	3	Y	N	R	R	

* Abbreviations are defined in the footnote to Table 1.

TABLE 5
No Exercise Program, Ergonomic Training Program, Standard Rivet Guns*

Numb	R0	L0	R1	L1	R2	L2	EXER	ERGO	GUN	HAND	JOB
0293	4	4	5	4	4	3	N	Y	S	R	
0302	3	2	4	4	4	2	N	Y	S	R	
0608	4	3	3	3	3	3	N	Y	S	R	
0684	4	3	4	3	2	2	N	Y	S	R	
1199	4	3	3	5	3	3	N	Y	S	R	
1425	3	3	4	2	4	4	N	Y	S	R	
1668	7	7	7	7	6	6	N	Y	S	R	
1698	3	3	3	5	4	2	N	Y	S	R	
1800	3	4	3	4	2	1	N	Y	S	R	
2478	4	2	3	2	1	3	N	Y	S	R	
2481	3	3	4	3	3	2	N	Y	S	R	
2622	2	3	NA	NA	NA	NA	N	Y	S	R	yes
3236	5	4	6	5	3	4	N	Y	S	R	
3437	5	4	4	4	3	3	N	Y	S	R	
3679	3	4	3	4	3	3	N	Y	S	R	
4187	7	6	6	6	5	3	N	Y	S	R	
4461	5	5	4	4	5	3	N	Y	S	R	
4556	4	3	4	3	4	3	N	Y	S	R	
5072	6	5	5	4	7	6	N	Y	S	L	
5095	3	3	3	4	2	4	N	Y	S	R	
5118	5	4	5	5	4	4	N	Y	S	R	
5758	3	7	4	5	3	5	N	Y	S	R	
5803	2	2	2	2	2	2	N	Y	S	R	
6142	3	2	2	2	2	2	N	Y	S	R	
7267	4	4	NA	NA	NA	NA	N	Y	S	R	
7548	5	5	4	3	2	2	N	Y	S	R	
7928	3	4	3	2	2	2	N	Y	S	R	
7984	4	4	NA	NA	NA	NA	N	Y	S	R	
8448	3	2	NA	NA	NA	NA	N	Y	S	L	
8532	3	5	4	2	3	2	N	Y	S	R	
9261	2	3	5	3	3	3	N	Y	S	L	
9847	3	2	3	2	2	3	N	Y	S	R	
9898	4	3	2	3	3	3	N	Y	S	R	

* Abbreviations are defined in the footnote to Table 1.

TABLE 6
No Exercise Program, Ergonomic Training Program, Vibration-Dampening Rivet Guns*

Numb	R0	L0	R1	L1	R2	L2	EXER	ERGO	GUN	HAND	JOB
0935	2	2	4	3	3	2	N	Y	R	R	
2644	4	5	4	5	NA	NA	N	Y	R	R	yes
3177	4	4	4	3	5	3	N	Y	R	L	
3489	1	2	1	2	1	2	N	Y	R	R	
3497	3	4	3	3	6	4	N	Y	R	R	
3709	6	1	6	3	3	2	N	Y	R	R	
4015	4	3	5	2	4	4	N	Y	R	R	
4336	2	3	2	3	2	3	N	Y	R	L	
4858	3	3	4	3	5	5	N	Y	R	R	
5153	5	4	4	5	4	4	N	Y	R	R	
5494	1	2	2	2	2	2	N	Y	R	R	
5541	2	3	4	3	2	2	N	Y	R	R	
5915	4	3	3	2	2	3	N	Y	R	R	
7113	3	3	2	1	4	3	N	Y	R	R	
8000	4	1	4	3	3	2	N	Y	R	R	
8402	1	2	3	1	1	1	N	Y	R	R	
8579	4	1	NA	NA	NA	NA	N	Y	R	R	
8808	4	4	4	4	NA	NA	N	Y	R	R	
9272	3	3	NA	NA	NA	NA	N	Y	R	R	
9291	2	3	2	3	2	3	N	Y	R	R	

* Abbreviations are defined in the footnote to Table 1.

TABLE 7
Exercise Program, Ergonomic Training Program, Standard Rivet Guns*

Numb	R0	L0	R1	L1	R2	L2	EXER	ERGO	GUN	HAND	JOB
0511	3	4	3	3	2	3	Y	Y	S	R	
0713	5	4	3	3	4	4	Y	Y	S	R	
0790	5	5	4	5	3	3	Y	Y	S	R	
0873	5	3	5	3	5	3	Y	Y	S	R	
0989	4	3	7	3	5	4	Y	Y	S	R	
1808	4	2	4	2	3	2	Y	Y	S	R	
2062	4	2	3	3	3	2	Y	Y	S	R	
2223	2	3	2	3	2	3	Y	Y	S	R	
2770	5	3	3	3	4	3	Y	Y	S	R	
3125	3	3	NA	NA	NA	NA	Y	Y	S	R	yes
3840	3	3	3	2	4	3	Y	Y	S	R	
3859	2	3	2	1	3	3	Y	Y	S	R	
4470	5	3	4	2	5	3	Y	Y	S	R	
4602	4	3	3	2	1	2	Y	Y	S	R	
5011	4	3	3	3	3	3	Y	Y	S	R	
5079	4	2	5	2	4	2	Y	Y	S	R	
5460	7	6	6	6	6	6	Y	Y	S	R	
5553	1	2	4	3	3	3	Y	Y	S	R	
6017	2	2	2	2	3	2	Y	Y	S	R	
6063	5	4	4	5	4	4	Y	Y	S	R	
6292	5	3	4	2	3	2	Y	Y	S	R	
6532	7	4	6	4	5	4	Y	Y	S	R	
6713	3	2	3	2	3	3	Y	Y	S	R	
6824	4	5	4	5	5	5	Y	Y	S	R	
7159	3	3	3	3	NA	NA	Y	Y	S	R	yes
7806	4	2	5	2	3	3	Y	Y	S	R	
8029	2	3	NA	NA	NA	NA	Y	Y	S	R	
8471	4	4	3	3	3	3	Y	Y	S	R	
9565	7	6	7	7	5	5	Y	Y	S	R	

* Abbreviations are defined in the footnote to Table 1.

Timerout: Time spent routing parts.
Npartsr: Number of parts routed.
Timesaw: Time spent sawing.
Partsaw: Number of parts sawed.
Ryrs: Number of years' experience riveting.
Yrs: Number of years worked.

The four-way experimental design for ergonomic posture training, exercise training, and rivet gun type (primary factors) resulted in eight study groups (Tables 1 through 8).

Results

Three main factors—ergonomic posture training, exercise training, and type of rivet gun—were compared with the control group to determine their effect on risk level for UECTDs. In addition, data were collected on the covariates for potential effects or impact on the three main factors' ability to change the individual's risk level. Ergonomic posture training was the only main factor to demonstrate a statistically significant impact (beneficial or detrimental) on risk level. Ergonomic posture training resulted in a decreased individual risk level or a beneficial impact.

When the covariates were analyzed along with the three main factors, additional interactions were established. The type of rivet gun used vibration dampening or standard—did not have a statistically significant effect either by itself or in combination with ergonomic training, exercise training or both. If the newly hired group (number of years worked) was compared with the previous employees' group, the vibration-dampening rivet gun demonstrated a reduction of individual risk. This reduced risk was considered to be the result of a learning curve with the new equipment. Individuals who were accustomed to the vibratory feedback of the standard rivet gun found it difficult to determine the end point of riveting with the vibration-dampening gun and tended to over-rivet and produce more rework parts. This conclusion was supported by review of the hours spent riveting and number of rivets driven.

A statistically significant relationship with the three groups listed below was determined. The relative reduction of risk was defined by the MAP risk score of 1 as minimum risk and 7 as maximum risk. The number in parentheses represents the level of change based on the risk score. A negative number indicates a reduction in individual risk whereas a positive number indicates increase in individual risk.

Ergonomic posture training: dominant hand (−1.00), time spent in an awkward position (−0.75), and

TABLE 8
Exercise Program, Ergonomic Training Program, Vibration-Dampening Rivet Guns*

Numb	R0	L0	R1	L1	R2	L2	EXER	ERGO	GUN	HAND	JOB
0219	4	4	3	3	4	5	Y	Y	R	R	
0358	5	4	4	3	2	4	Y	Y	R	R	
0582	2	3	2	3	2	3	Y	Y	R	R	
0862	4	3	3	2	4	3	Y	Y	R	R	
2405	3	2	4	5	3	2	Y	Y	R	R	
3186	3	2	3	2	2	2	Y	Y	R	R	
3310	4	3	3	3	4	3	Y	Y	R	R	
3748	2	2	2	1	2	1	Y	Y	R	R	
3780	5	1	4	3	5	3	Y	Y	R	R	
3958	1	2	3	3	3	3	Y	Y	R	R	
4379	3	4	2	3	2	3	Y	Y	R	R	
4449	5	5	5	3	5	4	Y	Y	R	R	
4488	3	3	2	3	3	2	Y	Y	R	R	
5107	4	6	3	3	3	3	Y	Y	R	R	
5217	3	1	2	3	1	4	Y	Y	R	R	
5256	4	3	3	3	3	3	Y	Y	R	R	
5472	4	3	4	3	4	4	Y	Y	R	R	
6807	2	2	4	4	3	3	Y	Y	R	R	
7876	4	5	4	5	5	5	Y	Y	R	R	
8521	4	4	3	4	2	3	Y	Y	R	R	
8734	5	4	NA	NA	NA	NA	Y	Y	R	R	
9250	5	3	3	3	3	3	Y	Y	R	R	

* Abbreviations are defined in the footnote to Table 1.

number of standard rivets bucked (−0.72).

Exercise training: dominant hand (−1.00), number of parts routed (−0.88), and number of parts ground (−0.74).

Vibration-dampening rivet gun: number of rivets bucked (−2.30), new hire (−2.00), and current employee (+1.25).

Discussion

The recognition and control of occupational injuries has resulted in the growing need for prospective studies on the etiology and prevention of UECTDs. Most UECTD studies have been based on the people, materials, methods, machines, and environment model. This prospective study was designed to determine the roles of ergonomic posture training, exercise training, and rivet gun type as they related to decreasing the risk to the individual of developing UECTDs. Covariates were compared with the primary factors for their impact on the reduction of risk for the individual.

This study included 212 workers assigned to the one of four primary factor groups: ergonomic posture training, exercise training, rivet gun type, and a control. During the 15-month study, data obtained from the MAP were statistically analyzed to identify the risk level on a scale from 1 to 7 for the probability of developing UECTDs. At the completion of the study, a model was developed to evaluate the groups for changes in the level of risk.

Of the main factors, ergonomic posture training was the only main factor to demonstrate a statistically significant effect on risk level by decreasing the individual's risk level. Neither exercise training nor the vibration-dampening rivet gun demonstrated a statistically significant effect to risk level on their own because of the large number of variations as a result of the covariates. Additionally, the type of rivet gun used—vibration-dampening or standard—did not have a statistically significant effect either by itself or in combination with ergonomic posture training, exercise training, or both.

Analysis of the covariates' interaction with the primary factors demonstrated a statistical significant relationship for the following groups: (1) risk reduction for ergonomic posture training and dominate hand, time spent in an awkward position, and number of standard rivets bucked; (2) risk reduction for exercise training and dominant hand, number of parts routed, and number of parts ground; (3) risk reduction for vibration-dampened and number of rivets bucked and newly hired employees; and (3) risk increase for vibration-dampening rivet gun and current employees.

As a result of this study, the employer was able to determine that vibration-dampening rivet guns with present materials, methods, machines, and environment would not be beneficial for all employees. The average cost of a standard rivet gun is $275 versus $700 for the vibration-dampening gun. The cost savings to the employer was over $3.4 million.

The results of this study suggest that ergonomic posture training and exercise training can provide benefits for workers outside of aircraft manufacturing. Current prospective

studies are demonstrating that decisions concerning the training of other types of workers, including office personnel, medical personnel, video display terminal users, and services provider personnel, can be based on statistical analysis of individual risk as provided by the MAP.

Summary

The recognition and control of UECTDs continues to be a major concern of employees, employers, medicine, and the federal government. UECTDs are identified by the National Institute for Occupational Safety and Health as one of the ten most significant occupational health problems in the United States, with estimates that by the year 2000, 50 cents on the dollar will be spent for their treatment. Enlightened aircraft employers have developed primary prevention strategies, however, primary prevention can never be expected to be 100% effective. The need for individual risk evaluation and the relationship of risk to materials, methods, machines, and the environment have taken on increased importance. In cooperation with a major aircraft manufacturer, this prospective study was implemented to objectively identify the relationship of work and activities to an individual worker experiencing CTDs. A statistical model was developed for the level of CTD risk and evaluated using the SAS software program. Statistical analysis of the primary factors without regard to covariates demonstrated that only exercise posture training had a beneficial reduction in risk for the individual. When the covariates were analyzed in conjunction with the four experimental groups, a positive benefit from ergonomic posture training and exercise training was demonstrated for the following groups: the dominant hand, time spent in an awkward position, number of standard rivets bucked, number of parts routed, number of parts ground, number of vibration-dampening rivets bucked, and newly hired employees. A detrimental impact on the current employees and vibration-dampening rivet gun was demonstrated. This prospective study helps to identify the possible benefit of education and training for controlling CTDs and demonstrates the usefulness of being able to evaluate materials, methods, machines, and environments at they relate to the individual's risk level for the development of UECTDs.

Acknowledgments

This study was funded by The Hand Center P.A., Wichita, Kan. The author thanks Peggy Gardner, PhD, Executive Director and Research Director of Medical Education, Via Christi Regional Medical Center, Wichita, Kan., for her review of the manuscript, and the Manufacturing, Research, & Development Group (Charles McNeil, James D. Riggs, Elizabeth Clarkson, and David McConeghey) for their assistance with the study.

References

1. American College of Occupational and Environmental Medicine. *Work Injuries and Illnesses by Selected Characteristics.* [USDL 94-213.] Washington, DC: US Department of Labor; November 1992.
2. Bureau of Labor Statistics. Repetitive tasks loosen some workers' grip on safety and health. *Issues.* 1994;94:1–2.
3. Melhorn JM. CTD: carpal tunnel syndrome, the facts and myths. *Kans Med.* 1994;95:189–192.
4. Melhorn JM. Occupational injuries: the need for preventive strategies. *Kans Med.* 1994;95:248–251.
5. Melhorn, JM. Cumulative trauma disorders: how to assess the risks. *J Workers Comp.* 1996;5–2 (Winter):19–33.
6. Melhorn JM. CTD injuries: an outcome study for work survivability. *J Workers Comp.* 1996;5–3 (Spring):18–30.
7. SAS Institute. Statistics. *SAS/STAT User's Guide.* Cary, NC: SAS Institute Inc.; 1985.