An Outcomes Study of an Occupational Medicine Intervention Program for the Reduction of Musculoskeletal Disorders and Cumulative Trauma Disorders in the Workplace

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Upper-extremity musculoskeletal pains or disorders (MSDs) account for a significant number of work-related illnesses in the US workforce. Although the concept of MSD prevention is appealing, little has been done to demonstrate the successful application and benefit of these programs. In 1995, an aircraft manufacturer established a unique risk-management program based on the individual risk assessment (CtdMAP™) for new hires. The MSD intervention program was designed to prospectively evaluate each new employee for their individual risk of developing MSDs in the workplace. Before job placement, individuals at higher risk were assigned to a period of transitional work. Workers' compensation costs decreases per year were 16%, 3%, 24%, and 12%, while work hours increased by 56%. Employer-estimated savings in direct workers' compensation costs per year were $469,990, $678,337, $1,936,105, and $1,995,759.

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The recognition and control of occupational injuries involving musculoskeletal pain (musculoskeletal disorders, or MSDs) has become a major concern of employees, employers, medical professionals, and the federal government because of the negative impact of these common injuries on worker health and long-term productivity. The impact is measurable as the MSD contribution to workplace risks, health and safety costs, injury rates, lost work time, treatment duration, and workers' compensation costs. Various names have been used for MSDs, including cumulative trauma disorders (CTDs) and repetitive motion injuries. Effectively reducing the incidence of MSD would reduce total costs, increase corporate productivity, and improve employees' quality of life.

In 1990, the National Institute for Occupational Safety and Health (NIOSH) estimated that 15% to 20% of Americans were at risk for developing CTDs.[1] As recently as 1995, the US government predicted that by the year 2000, 50% of the American workforce will have occupational injuries annually, and 50 cents of every gross national product dollar will be spent on occupational injuries.[2] In 1997, the cost of workplace health and safety was estimated at over $418 billion in direct costs and—using the lower estimates—over $837 billion in indirect costs, for a total cost of over $1.26 trillion.[3] According to the Occupational Safety and Health Administration (OSHA) Office of Ergonomic Support, MSDs are responsible for 33% to 40% of workers' compensation claims.[4] The high costs of MSDs make them a high priority for strategic planning to prevent or reduce their incidence.

There is evidence that the number of MSD injuries and illnesses may be decreasing. In 1998, the Bureau of Labor and Statistics[5;6] released results of its 1996 annual survey of lost work time due to injuries and illnesses. The data revealed that a total of nearly 1.88 million injuries and illnesses in private-industry workplaces required recuperation away from work beyond the day of the incident. This represents a decline of 8% from the 2.04 million cases reported in 1995. In fact, the number of injuries and illnesses resulting in time away from work declined throughout the period from 1992 through 1996 (from 2.24 million cases in 1992, the number declined by 3.4% in 1993, 0.7% in 1994, 8.7% in 1995, and 7.9% in 1996.) Although the decline in numbers of injuries is important, it does not represent trends in injury severity, worker productivity, or workers' compensation costs.

Injury-severity measures demonstrate that MSDs remain a serious and costly problem in the workplace. The number of lost workdays per MSD case have increased, with MSD cases contributing disproportionately more lost workdays per case (median number of lost workdays in 1996 was 5 days for all cases but 25 days for MSD cases).[6] Webster and Snook[7] reported the mean cost per MSD/CTD case to be ten times higher than costs per case for other workplace injuries (ie, a mean cost of $8070, compared with a mean cost for all other cases of $824). Most of the MSD/CTD costs were due to indemnity costs (65.1%), rather than to medical costs (32.9%).

Longer treatment duration appears to be responsible, in part, for the higher costs associated with MSD injuries. Feuerstein et al[8] reported 185,927 claims in the federal workforce from October 1, 1993, to September 30, 1994. The mean number of lost workdays was 84 for only one MSD—carpal tunnel syndrome (CTS)—at a direct medical cost of $4941. They concluded that upper-extremity MSDs incurred significantly higher direct and indirect medical costs because of the longer treatment duration and greater work disability.

These facts support the need for early identification and prevention of MSDs. NIOSH stated the need for a national prevention strategy over a decade ago[2;9] Feuerstein et al[8] restated the need in their 1994 study.

Prevention and/or early intervention strategies are more cost-effective when applied to specific segments of the population that have an increased risk of developing the disease of interest; in this case, MSDs. One study suggests that risk levels are higher in ten specific occupations; these occupations accounted for nearly one third of the injuries and illnesses requiring recuperation away from work for the period 1992 through 1996.[6] These occupations are truck drivers, laborers (nonconstruction), nursing aides/orderlies, janitors and cleaners, assemblers, construction laborers, carpenters, stock handlers and baggers, cashiers, and cooks. Cheadle et al[10] investigated patterns of work-related disability in Washington State workers' compensation cases from 1997 to 1999. Although over half of all claimants (all injuries, neck/back sprains, fractures) returned to work within the first month and were no longer receiving disability payments, those with upper-extremity work-related injuries took a disproportionately longer time to return to work, with 17.5% of all carpal tunnel syndrome claims resulting in at least 6 months of lost work time: 12% had 12 months of lost work time, and 7.4% were off work for at least 2 months. Early, effective screening and prevention and intervention efforts aimed at higher-risk employees may be able to prevent or reduce disability.

The effectiveness of workplace screening programs for the reduction of MSDs cannot be measured only by the Bureau of Labor Statistics incidence rate.[5;6] Screening contributes to the prevention of work-related disease when individual and group test results are routinely scrutinized for indications of adverse health effects, and appropriate actions are taken in response to such findings.[11] Golaszewski et al[12] demonstrated that for every dollar spent on general health prevention, 3.40 dollars are saved (benefit-to-cost ratio). Nevertheless, employers have been reluctant to undertake workplace screening because of concerns that the process of screening and the associated education might cause an increase in the reporting of OSHA 200 events, an increase in requests for medical care, and an increase in workers' compensation claims, thereby resulting in increased workers' compensation costs. A prospective study by Melhorn[13] suggested that these concerns may be unwarranted. No increases in the reported number of OSHA 200 events or in incidence of workers' compensation claims after completion of an individual MSD risk-screening program that included education and employee awareness about work-related musculoskeletal pain. The possible beneficial effects of screening on indemnity costs was not examined.

Unfortunately, there is a long history of difficulties in differentiating individual risk factors from workplace risk factors.[14] Recent studies suggest that occupational diseases involve multiple etiological factors and that a specific job may not be the primary cause for their occurrence.[15–26] When this literature is reviewed, a number of questions arise regarding etiology and job relationship; however, sufficient epidemiological evidence is present to demonstrate an association between an individual's risk and activities (workplace and non-work environment).[27;28] Evidence suggests that prevention is the best approach to the reduction of MSDs and that prevention is best achieved via individual screening and surveillance in the workplace.[11,28–33]

Currently there is little data regarding applications of workplace risk reduction programs for MSD. There is, however, common agreement on the need for a reduction of MSDs in the workplace. A truly effective MSD intervention program would be expected to increase awareness and earlier reporting of MSD injuries, and, perhaps, result in higher MSD injury incidence rates. However, the same MSD program would decrease the total number of lost workdays, lost time case incidence rate, lost time day severity rate, and workers' compensation costs, while increasing production and corporate profits.[34] The lack of prevention models is likely due to one or more of the following: (1) limited agreement on the appropriate case definition for MSDs that occur in the workplace; (2) the lack of an ergonomic and epidemiologic model for MSDs; and (3) the lack of scientific evidence on specific dose and exposure relationships occurring in the workplace, in the individual, and on the job.

The evidence emphasizes the causes for concern relating to MSDs. Although designing and implementing effective intervention programs to reduce risks is difficult, the potential benefits of a program that that is only partially successful would be expected to result in substantially improved workplace health and safety, reduced injury incidence rates, decreased lost work time, decreased treatment duration, and decreased workers' compensation costs.

This study was designed to provide and evaluate the effects of a proactive program in an aircraft manufacturing company to (1) identify employees at increased risk of MSDs, (2) provide specific, targeted interventions to reduce risk and prevent MSDs, and (3) maintain high productivity.

Methods

The MSD Intervention Program

In January of 1995, an aircraft manufacturer established a unique, prospective quality improvement study based on MSD risk management, using an individual risk-assessment instrument and a specific group of risk-reduction strategies. OSHA[35] and NIOSH[36] have provided guides for the development of ergonomic prevention programs. The current MSD intervention program was designed to integrate a traditional occupational medicine clinic (physician on site) and a disease-specific individual risk assessment instrument for assigning risk and implementing intervention. This five-step program includes all current suggestions provided from the OSHA and NIOSH guides and is outlined in Table 1. The foundation for this combined approach is supported in many studies.[37–43] The main objective of the MSD intervention program was to reduce the costs of MSDs of the upper extremities, lower extremities, and back, without reducing production and without incurring higher production-related costs.

For this study, all new hires for the period beginning January 1995 and ending January 1998 (n = 3152) who were considered for the job of sheet metal mechanic were included in the intervention program. Each participant received the same post-hire pre-placement assessment, which included a formal history and physical examination by a physician, the individual risk assessment, a match to current hiring requirements (jobs available), and a match to essential functions of the job. The standard protocol was followed for each new hire in accordance with the

TABLE 1
The Five Steps of the Intervention Program

1. Organization
   - Employer commitment
   - Prevention committee
   - Medical consultants
2. Data collection and protocols
   - Problem identification
   - Data collection
   - Protocols
     - Ergonomic
     - Medical
     - Educational
3. Risk identification
   - Risk-assessment instrument
   - Individual risk factors
   - Employer or workplace risk factors
4. Risk analysis
   - New data collection
   - Analysis affects
   - Review of protocols
5. Risk resolution plan
   - Recommendations
   - Implementation of change
     - Ergonomic
     - Education
     - Engineering modification
     - Design changes

Repeat steps 3, 4, and 5 for Total Quality Management

Americans with Disabilities Act guidelines.[44–52] Individual risk assessment was completed using the CtdMAP™ instrument (Map Managers, Inc., Wichita, KS). The CtdMAP™ instrument was selected because it meets the requirements of an outcome instrument, is disease-specific for MSDs, and has previously been validated.[38–42;53–57] The CtdMAP™ instrument contains 137 questions and 56 physical measurements and takes approximately 40 minutes to complete. In a risk range of 1 to 7, 4 is the average, 1 to 3 is below average, and 5 to 7 is above average risk for the development of musculoskeletal pain. The individual risk scores by group are listed in Table 2.

Using company information regarding the essential functions of each job, an algorithm was developed for implementation of the MSD

TABLE 2
Individual Risk Scores

Upper-Extremity Risk Scores, by Group	Number	% of Total	% of Scores 5, 6 and 7	Lower Extremity and Back Risk–Positive	% of Total	% of Scores 5, 6 and 7
All	3152	100		189	6	
1 to 4 average and below average	2391	76		24	1	
5 To 7 above average	761	24		165	5	
5	631	20	83	121	4	73
6	96	3	13	30	1	18
7	34	1	4	14	0	8

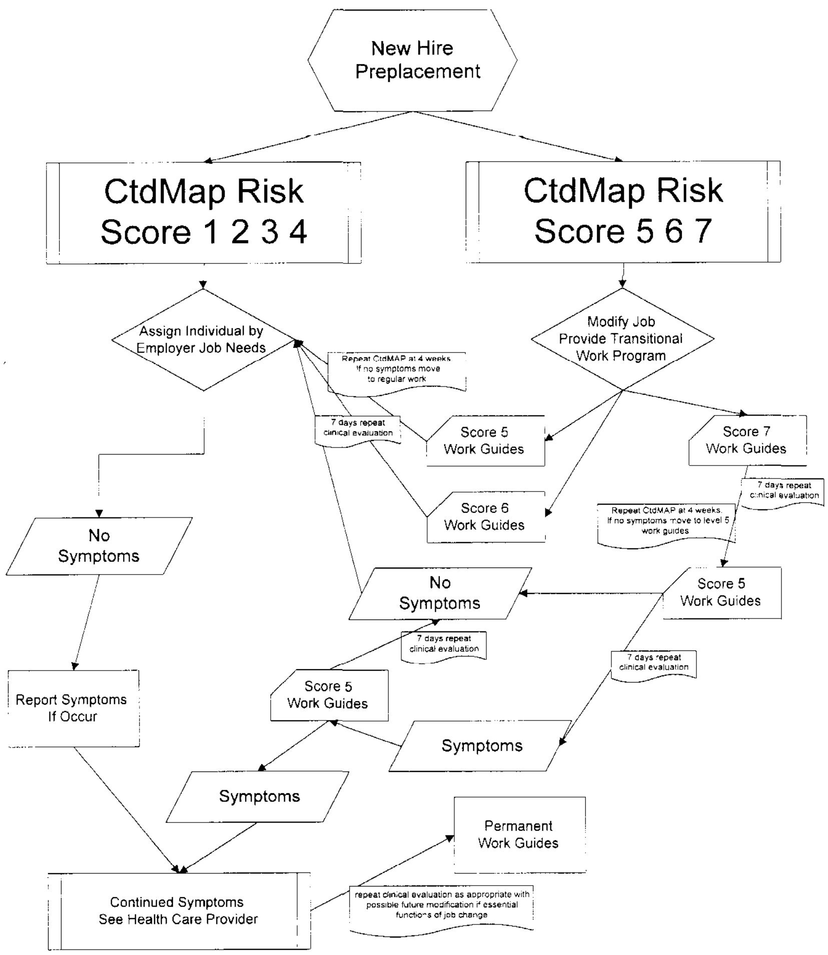

Fig. 1. New hire–preplacement algorithm.

intervention program, as shown in Fig 1. Individuals with individual CtdMAP™ scores of 4 and below (n = 2391, or 76%) were integrated into the workforce on the basis of current hiring requirements (jobs available) (Table 3). Individuals with risk scores of 5 and higher (n = 761, or 24% of the total [n = 3152]) were assigned to transitional (temporary) work. Transitional work consisted of the same job activities but placed limits on the number of hours that certain aspects of the job could be performed (Table 3). For individuals with a risk score of 5 (n = 631, or 83% of the high-risk group [n = 761]), the transitional period included use of power and vibratory tools limited to 7 hours per 8-hour day in time blocks of 1¾ hours per 2 hours repeated for an 8-hour day; and repetitive motion limited to 7 hours per 8-hour day in blocks of 55 minutes per 1 hour. A risk score of 6 (n = 96, or 13%) required limiting power and vibration ory tools to 6 hours per 8-hour day in time blocks of 1½ hours per 2 hours repeated for an 8-hour day and limiting repetitive motion to 6 hours per 8-hour day in time blocks of 50 minutes per 1 hour repeated for 8-hour day. A risk score of 7 (n = 34, or 4%) resulted in limiting power and vibratory tools to 4 hours per 8-hour day in time blocks of 1 hour per 2 hours repeated for an 8-hour day and limiting repetitive motion to 5 hours per 8-hour day in time blocks of 40 to 50 minutes per 1 hour repeated for an 8-hour day. Individuals with higher risk for lower extremity and back injuries (n = 165, or 5% of total) were instructed in appropriate body mechanics and lifting techniques.

Employees with CtdMAP™ risk scores of 5, 6, or 7, were reevaluated by the occupational physician at 4 weeks. If they were asymptomatic for musculoskeletal pain, those workers with risk scores of 5 or 6 resumed regular work without restrictions and were instructed to immediately report the occurrence of any symptoms. Those with risk scores of 7, if they were asymptomatic, were provided with risk score 5 transitional work guides for 7 days, followed by a reevaluation. At the 7-day follow-up, if they were cur-

TABLE 3
Transitional Work Guides

Risk Level	Vibratory/Power Tools	Repetitive Motion
1 To 4	None, if asymptomatic	None, if asymptomatic
5	7/8 Hours in 1¾ per 2 hours	7/8 In 55 minutes per 1 hour
6	6/8 Hours in 1½ per 2 hours	6/8 In 50 to 55 minutes per 1 hour
7	4/8 Hours in 1 per 2 hours	5/8 In 40 to 50 minutes per 1 hour

rently asymptomatic, they were advanced to regular work without restrictions and instructed to immediately report the occurrence of any symptoms. At the 7-day follow-up, if they were currently symptomatic, they were returned to risk score 6 transitional work guides for 7 days and the evaluation process was repeated until they were asymptomatic. Only 11 of the 34 (29%) with risk scores of 7 required permanent restrictions at the level of the risk score 6 transitional work guides; that is, vibratory or power tools limited to 6 of 8 hours in time blocks of 1½ hours per 2 hours and repetitive motion limited to 6 of 8 hours in time blocks of 50 to 55 minutes per hour. This number represents less than 1% of the original high-risk group (risk scores 5 to 7, n = 761) and only 0.4% of the entire study group originally screened.

Medical management protocols were not changed for the study. The on-site occupational physician and health services personnel saw every employee who reported developing work-related musculoskeletal pain. The medical treatment protocols used for all eligible employees (the new hires "study group" and other employees "non-study group") were similar to the medical management protocols used during the comparison years of 1990 through 1994.

Outcome Measures and Data Collection

Six outcome measures were used to evaluate the MSD intervention program effects. To address the effects of potential confounding variables, the following were also evaluated: (1) annual number of hours worked per employee; (2) annual average number of employees and new hires; (3) annual data on the same measures from the two other companies within the same parent company in which sheet metal worker was a primary job, and (4) annual data from a second facility in the same company that opened in 1994. All data were provided by the employer for several years before and after implementation of the intervention program.

The study measures included the following:

1. *Recordable Case Incidence Rate*: The number of OSHA 200 recordable injuries or illnesses that occurred per 200,000 hours worked (RCIR). OSHA 200 injuries are defined as any injury—for example, cuts, fractures, sprains, amputations—that results from a work accident or from a single instantaneous exposure in the work environment.[27] OSHA 200 illnesses are defined as any abnormal condition or disorder, other than none resulting from an occupational injury, caused by exposure to environmental factors associated with employment[27] As discussed in the introduction, this measure has some important limitations; therefore, the following measures were also taken through 1994; the post-program initiation period included years 1995 through 1998.
2. *Lost Time Case Incidence Rate (LTCIR):* The subset of measure 1 above that resulted in the employee's being unable to return to work (regular work or restricted work) on the next scheduled workday. This rate is often expressed as days away from work and is an excellent indicator of disability rate, ie, the number of cases in which they were unable to perform any work activity. It is closely related to workers' compensation costs.
3. *Lost Time Day Severity Incidence Rate (LTDSIR)*: The number of workdays away from work for the subset of measure 1 above who are unable to return to regular work or for whom the employer is unable to accommodate in temporary restricted work. This measure is the most difficult for employers to affect via established administrative changes; therefore, it directly relates to quality of life issues for the injured employee.
4. *Airplane production*: The number of aircraft produced and general information on the number of different types and models of aircraft produced were measured. No information was collected on tools, machinery, or model complexity that were changed.
5. *Costs of the intervention program*: Three types of cost measures were used: (i) costs directly related to the individual risk assessment ($39 per assessment to administer); (ii) costs of transitional work related to intervention protocols; that is, hourly wages multiplied by number of hours of restrictive work that prohibited or required different job tasks; (iii) costs for the educational classes in terms of employee time away from work multiplied by their hourly wage plus the instructor costs; and (iv) administrative costs related to managing the program, measured in terms of physician and staff time multiplied by their hourly wages.
6. *Estimated workers' compensation costs*: Estimated workers' compensation costs per individual were measured.

All six of these rates were calculated per employee or per 200,000 hours worked. The 200,000 hours

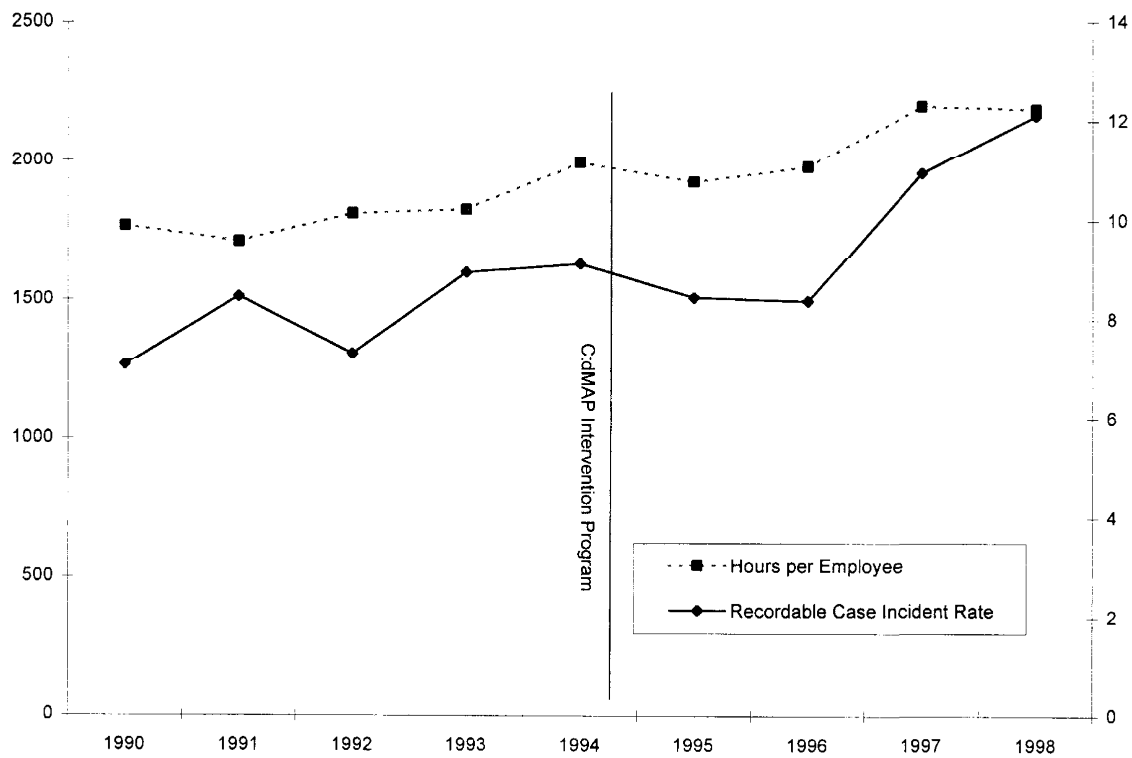

Fig. 2. Recordable Case Incident Rate (RCIR; Occupational Safety and Health Administration [OSHA] 200 events) and work hours per employee before and after the cumulative trauma disorder (CTD) intervention program.

figure was chosen to represent the hours worked by 100 people in a standard work year (2080 hours minus 80 hours of vacation). The pre-program period included the years 1990 through 1994. The post-implementation period included the years 1995 through 1998.

Results

RCIR per 200,000 Hours Worked

As a simple, unadjusted measure of injury and illness rates, the RCIR showed no specific trend prior to implementation of the MSD prevention program, ranging between 7.09 and 9.13. Post-implementation RCIR rates remained within this range during the first 2 years (8.44 and 8.37, respectively) but increased during the last 2 years (10.95 and 11.41, respectively). As shown in Fig 2, a significant correlation was seen between the RCIR and the number of hours worked per employee for the entire 9-year period ($r = 0.75$, $P < 0.05$) but not for the two separate pre-intervention and post-intervention periods. This suggests that the increases in injury rates may have been related to the increasing number of hours worked per employee

LTCIR per 200,000 Hours Worked

Using the LTCIR as an indicator of disability rates and workers' compensation costs, a significant increase (25%) was seen during the pre-program period of 1990 to 1994 (from 1.69 to 2.12), followed by a dramatic decrease of 71% during the program implementation period of 1995 to 1998 (6% decrease in 1995, 32% decrease in 1996, 39% decrease in 1997, and 24% decrease in 1998). This occurred despite the increasing numbers of hours worked per employee and increasing workforce numbers (Fig 3). A strong and statistically significant correlation is seen between the LTCIR and the number of new hires for the 9-year study period. Upon closer examination, the correlation is due primarily to a strong negative correlation after implementation ($r = -0.99$, $P < 0.01$). That is, the dramatic RCIR reduction during the post-implementation period is related to the number of new hires during the same period.

LTDSIR per 200,000 Hours Worked

The LTDSIR is an indicator of injury severity and is the best outcome measure for estimating workers' compensation costs. The pre-implementation rate increased dramatically by 89% from 1990 to 1992 and by another 16% from 1992 to 1994 (rate = 1991 rate, 31.8; 1994 rate, 69.78). The rate declined after the program's implementation, by 6% in 1995, and major declines were seen in 1996 (76%), 1997 (43%), and 1998 (52%). A total decline of 88% was seen from 1995 to 1998 despite a 56% increase in the number of

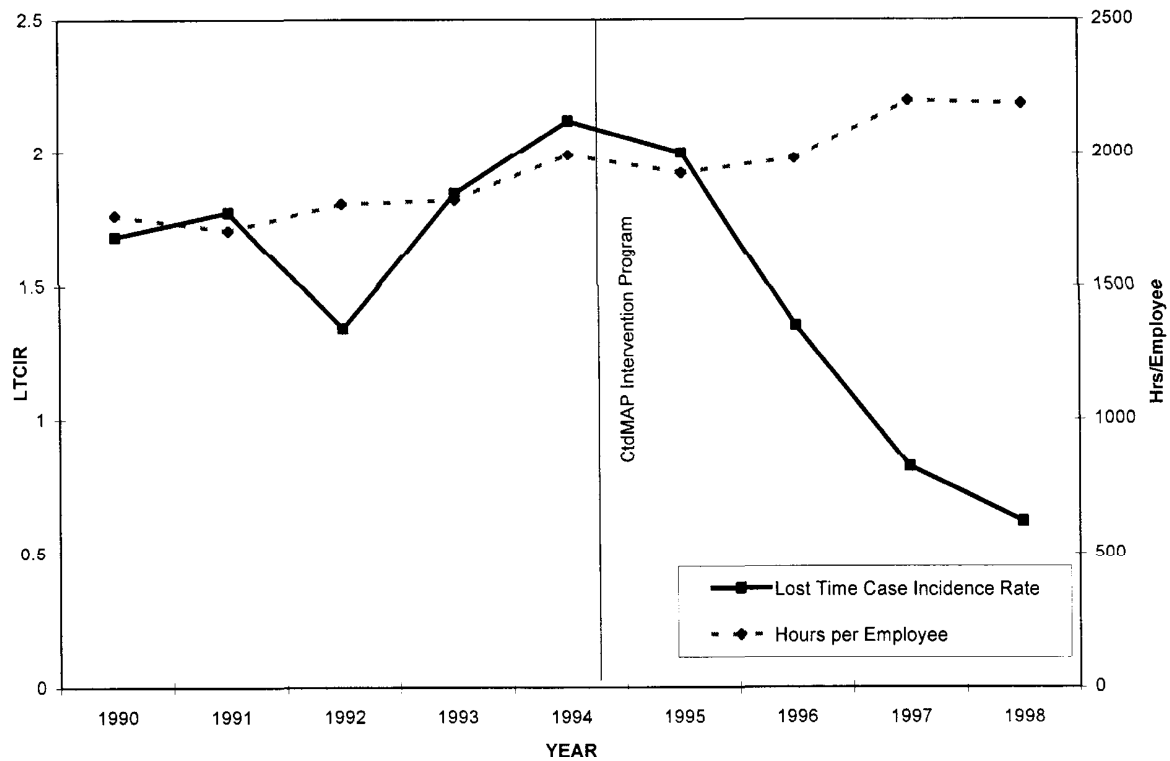

Fig. 3. Lost Time Case Incident Rate (LTCIR; OSHA 200 events) by hours worked per employee before and after the CTD intervention program.

Fig. 4. Lost Time Day Severity Rate (LTDSR; OSHA 200 events) by hours worked per employee before and after the CTD intervention program.

hours worked per employee and a 62% increase in the size of the workforce, as seen in Fig 4 for all employees and Fig 5 for new hires only. It is important to note that while hours per employee increased after the program's implementation, the LTDSIR dropped dramatically. However, as seen with the LTCIR, there is a

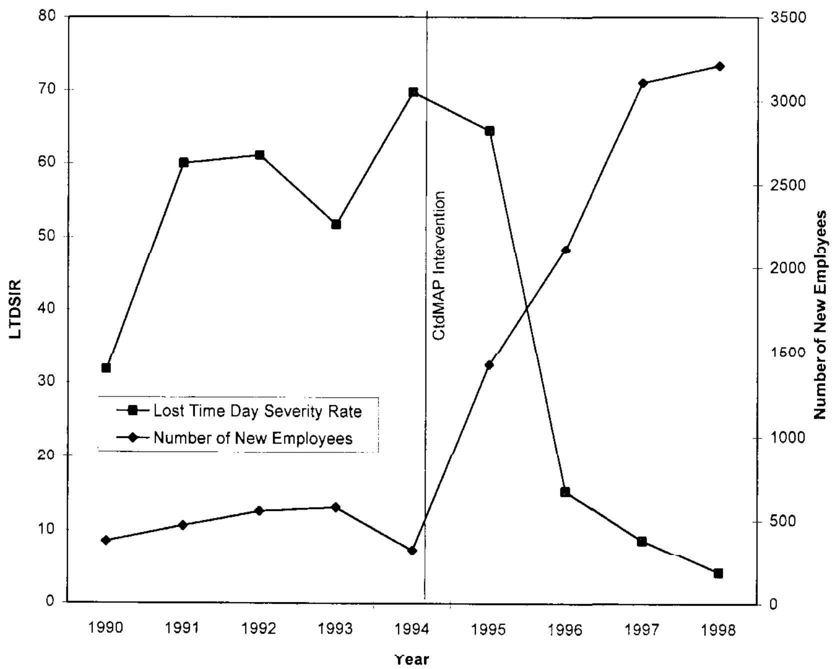

Fig. 5. Lost Time Day Severity Rate (LTDSIR; OSHA 200 events) by number of new employees.

strong negative correlation between the LTDSIR and the number of new employees after the program's implementation.

Employee and Environmental Changes in the Workplace

The total number of employees increased by 15% from 1990 through 1994, although there were major layoffs in 1994. During the pre-implementation period, new hires accounted for roughly 10% of total employees. During the post-implementation period, new hires accounted for approximately 16.6% in 1995, 25% in 1996, 33% in 1997, and 34% in 1998. The opening of a second facility in July 1996 is responsible, in part, for the increase in new hires for the subsequent years.

The opening of a second facility in July 1996 was evaluated as a potential confounder in the evaluation for the impact of the MSD risk-intervention program. In 1997, the employees from the second facility comprised 7% of total employees (second facility n = 710, primary facility n = 9082) and contributed 7% of all recordable injuries but only 1% of lost hours due to injuries and 4% of lost days due to injuries. The recordable injury rates per employee were the same (11%) for both facilities. Further, the employer shared that the MSD intervention program was not thoroughly implemented at the second facility because of the turnover in human resource staff. Both facilities experienced a 51% increase in work hours during 1997 and 1998 and similar recordable injury rates. The workforce decreased at the primary facility by 6% and increased at the second facility by 28%. Figures 6 and 7 show that the study company had the lowest workers' compensation costs at the beginning of the study, which dismisses the possibility that the study company had unusually high costs before the program which later normalized coincidentally with the program. In addition, the two comparison companies' costs did not decrease during the program years.

Airplane Production

The employer manufactures aircraft that are in the corporate jet and single-engine aircraft categories. During the 8-year study period, nine different aircraft models were produced. Using 1991 through 1994 as the baseline, the employer manufactured 161 aircraft per year in an

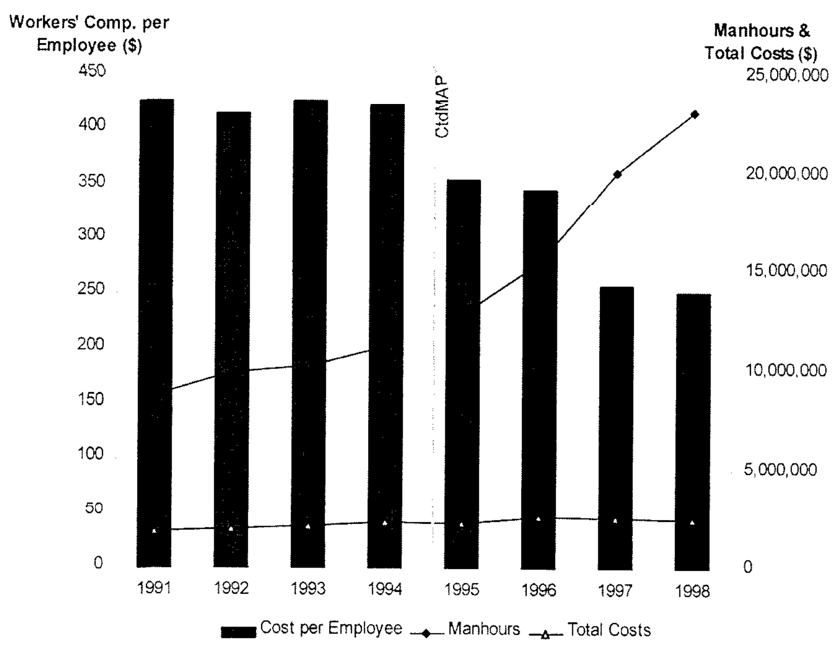

Fig. 6. Studied company's workers' compensation per employee.

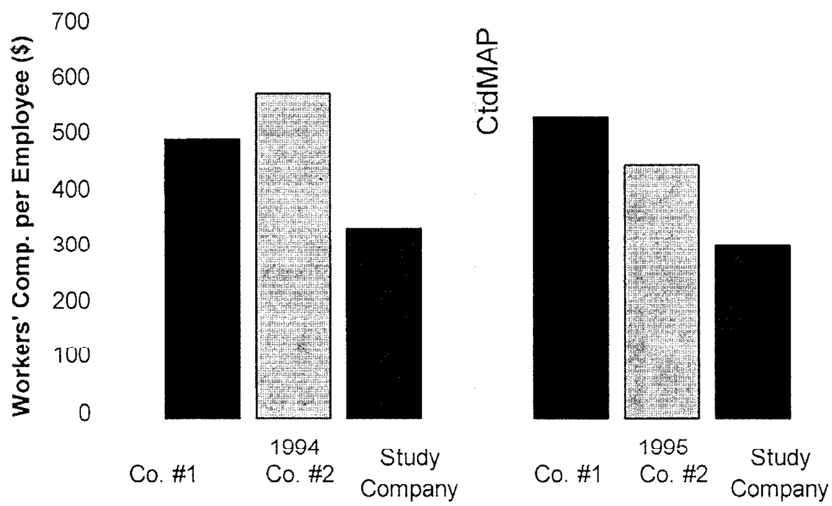

Fig. 7. Workers' compensation per employee, by company.

average time of 102 days, which translates into 0.0288 aircraft per employee and 1.58 aircraft per day. During the study period (1995 to 1998), the employer manufactured 236 aircraft in an average time of 120 days, which translates into 0.0287 aircraft per employee and 1.97 aircraft per day. At first glance, there appears to be a slight increase in productivity, but interpretation is limited by other uncontrolled factors, such as varying manufacturing demands, requirements, and complexity, and tool and machinery changes.

Risk-Intervention Program Costs

The total, 4-year program cost of the initial individual risk assessments was $122,928 for 3152 assessments. The 761 repeat assessments performed after the transitional work cost $29,679. The total cost of the transitional work intervention for upper extremities was $142,350. The costs for the body mechanics and lifting techniques class was $2,028. The total administrative cost was $7,485. Thus the total cost for the MSD intervention program over the 4 years was $304,470, or $76,118 per year. This represents less than 0.06% of the employer's annual salary costs.

Estimated Workers' Compensation Savings

Worker's compensation costs per employee are illustrated in Figure 6. During the pre-implementation period of 1990 through 1994, the costs remained relatively constant, with a high of $427 and a low of $415 per employee in a relatively constant total workforce. Post-implementation costs per employee dropped to $356, $346, $258, and $252, respectively, for 1995 to 1998. This drop occurred despite a 56% increase in work hours post-implementation.

Another potential confounder could have been that this employer's workers' compensation costs were disproportionately high before the start of the MSD intervention program. This employer is one of three companies (in three different states) under the same parent corporation whose employees perform similar work activities (sheet metal mechanic). Data were available for all three companies for 1994 and 1995. A comparison of the three companies' workers' compensation costs per employee, adjusted for each state's workers' compensation system relative cost,[58] is shown in Fig 7. The range is $579 to $340 for the before implementation period and $535 to $311 for the after implementation period.

For the years 1995 to 1998, the employer-estimated savings in direct workers' compensation costs were $469,990 the first year, $678,337 the second year, $1,936,105 the third year, and $1,995,759 the fourth year. The yearly cost of the MSD intervention program was $76,118. These figures result in a benefit-to-cost ratio for the MSD intervention program of 6 in the first year, 9 in the second year, 25 in the third year, and 26 in the fourth year.

Discussion

The MSD Intervention Program

The MSD intervention program for this study was designed to integrate a traditional occupational medicine clinic (physician on site) and a disease-specific individual risk assessment instrument for assigning risk and implementing intervention. The main objective of the MSD intervention program was to reduce the costs of MSDs of the upper extremities, lower extremities, and back, without reducing production and without incurring higher production-related costs. Five steps are outlined in Table 1: (1) organization, (2) data collection and protocols, (3) individual risk identification, (4) risk analysis, and (5) risk-resolution planning, which includes repeating steps 3, 4, and 5.

Evaluation of Outcomes

The increase in the RCIR rate of injuries and illnesses may reflect the encouragement by the employer for earlier reporting of all MSDs in the workplace and the relationship of increased hours worked per employee (Fig 2). Higher RCIRs do not directly relate to higher workers' compensation costs, as supported by several studies which demonstrated that earlier reporting results in less severe cases and, therefore, a decrease in overall workers' compensation costs.[12;59–66] This study's results would be consistent with those conclusions.

As an indicator of disability rate closely related to workman's compensations costs, the LTCIR rate increased before program by 25% from 1.69 to 2.12 but then dropped dramatically during the post-implementation period despite an increasing number of hours worked per employee and increasing numbers of employees (Fig 3). This suggests a strong beneficial effect of the intervention program.

The LTDSIR is the best indicator of injury or illness severity and is the best outcome measure for the dollar costs related to workers' compensation. The tremendous increases seen during the before program period show a clear contrast, with the major declines seen after program implementation. The total decline of 88% from 1995 to 1998 occurred despite a 56% increase in the number of hours worked per employee and a 62% increase in the number of employees (Fig 5).

The strong negative correlation seen between number of new hires and the LTDSIR after program implementation, which was not seen during the before program period, suggests that MSD intervention for new hires may be responsible for the dramatic decline in the LTDSIR. The stable CtdMAP© risk scores seen among new hires throughout the study period suggest that the reduction in the LTDSIR was not due to the company's adding new hires at lower risk for musculoskeletal pain, thus lending support to a strong beneficial impact of the intervention program.

Because aircraft manufacturing is a cyclical industry, the aircraft employee is frequently affected by fluctuations in employment levels. During this study, the total number of employees increased by 15% from 1990 through 1994, although there were major layoffs in 1994. The number of employees increased dramatically (62%) during the years after the program's implementation, with the largest increases seen in 1997 and 1998. The number of layoffs was greatest in 1994 (before implementation) and 1996 and 1997 (after implementation). The number of new hires increased each year from 1990 through 1993 and dropped in 1994. New hires accounted for roughly 10% of total employees during the pre-implementation period, whereas during the post-implementation period, new hires increased substantially as a proportion of total employees, accounting for 16.6% of total employees in 1995, 25% in 1996, 33% in 1997, and 34% in 1998. The opening of a second facility in July 1996 is responsible in part for the increase in new hires.

The opening of a second facility in July 1996 was seen as a potential confounder in the evaluation for the impact of the MSD risk-intervention program. In 1997, the second facility employed 7% of the total number of employees (second facility $n = 710$, primary facility $n = 9082$) contributed 7% of all recordable injuries but only contributed 1% of the lost hours due to injuries and 4% of the lost days due to injuries. The recordable injury rates per employee were the same (11%) for both facilities. This data confirms that the second facility was not responsible for the substantial decline in workers' compensation rates in 1997. To further support this conclusion, if the worse case scenario was assumed and the second facility had no workers' compensation costs for 1997, the combined decrease in workers' compensation costs would have been 20%, rather than the 25% observed.

The employer shared the information that the MSD intervention program was not thoroughly implemented at the second facility because of human resource staff turnover. This conclusion was supported by the following data: Both facilities had similar recordable injury rates for 1997. Both facilities experienced a 51% increase in work hours during 1997 and 1998. However, the average number of employees decreased in at the primary facility by 6% and increased by 28% at the second facility. Therefore, more work hours were performed per employee at the primary facility while the primary facility reported 16% less recordable injuries, 72% less lost days due to injuries, and 40% less lost hours due to injures. These facts lend further support for the benefit of complete implementation of the MSD intervention program.

Productivity, as an outcome measure, also improved during the study period. The study employer manufactures aircraft that are in the corporate jet and single-engine aircraft categories. During the 4 years before the study and the 4 years of the study, the employer manufactured nine different aircraft models. Using 1991 through 1994 as the baseline, the employer manufactured 161 aircraft per year in an average time of 102 days, which translates into 0.0288 aircraft per employee and 1.58 aircraft per day. During the study period (1995 to 1998), the employer manufactured 236 aircraft in an average time of 120 days, which translates into 0.0287 aircraft per employee and 1.97 aircraft per day. Although the models produced during the study period were more complex and required, on average, 18 more days to produce, the productivity of the workforce increased by 0.39 aircraft per day during the post-implementation period.

Evaluation of Costs

Costs related to MSD intervention programs have traditionally been difficult to assess. For this study, the costs for each part of the program were tracked prospectively and were organized into three groups: (1) costs directly related to the individual risk assessment; (2) costs related to intervention protocols (modified work activities); and (3) administrative costs related to managing the program. The individual risk-assessment cost was $39 per assessment to administer and score, for a cost of $122,928

(n = 3152 over the 4 years). Using the MSD intervention protocol, 761 individuals underwent a repeat assessment during their transitional work program, for a cost of $29,679. Total costs for individual assessments was $152,607. The costs of transitional work for the 761 employees with CtdMAP™ scores of 5, 6, or 7 were calculated by multiplying the number of hours of restrictive work that prohibited or required different job tasks by the individual employee's hourly wage. The cost for the 631 CtdMAP™ score of 5 was $82,030, for the 96 CtdMAP™ score of 6 was $24,960, and for the 34 CtdMAP™ score of 7 was $35,360. The total cost for transitional work for upper extremities was $142,350. The costs for the body mechanics and lifting techniques class were calculated as time away from work times the individual's wage plus the cost of the instructors, a cost of $2028. The cost to administrate the MSD intervention program for the physician and staff was $7485. The total cost for the MSD intervention program over the 4 years was $304,470, or $76,118 per year, which represents less than 0.06% of the employer's annual salary costs.

The workers' compensation costs per employee remained relatively constant during the before implementation period of 1991 through 1994, with a range of $427 to $415 per employee and an average of $423. However, significant changes were seen during the after implementation period of 1995 through 1998, with a range of $356 to $252. This range represented a drop in the workers' compensation cost per employee of 16% in the first year, 3% in the second year, another 24% in the third year, and another 8% in the fourth year. This drop in costs occurred despite a 56% increase in work hours during the same period (post-implementation).

To address a possible confounder, the higher initial workers' compensation cost of the study company, a comparison was made with the other two companies of the same parent corporation. All three companies' employees perform similar work activities of sheet metal mechanic in aircraft (study company), helicopter (Company 1), and automotive (Company 2) manufacturing of the same parent corporation (Fig 7). This type of comparison helps to decrease the affects that administrative corporate attitude would have on the reporting and response to work-related injuries. Data was available for 1994, in the before implementation period, showing a range of $579 to $340, and for 1995, in the after implementation period, showing a range of $535 to $311 after adjustment for the state's workers' compensation system relative cost.[58] The study company clearly did not start at a higher relative cost per employee for their workers' compensation costs.

Evaluation of Savings

Benefit-to-cost (savings for every dollar spent on prevention) can be calculated using actual costs or estimations of costs. Health care costs can be considered as direct or indirect.[67] For this study, only direct costs were considered, which included medical care (physician or other provider services), clinic or hospital care, ancillary diagnostic services, patient-specific medical supplies and equipment, medications, occupational/physical therapy, employee assistance counseling, workers' compensation payments (as applicable), sick pay (as applicable), and other benefits (as applicable).

Indirect costs related to workers' compensation are even more difficult to assign dollar amounts to but impact negatively on the profits of a company and are included for completeness. If these additional indirect costs had been considered, the savings would have been even greater than those reported. Indirect costs can be grouped as those that can be directly related to a specific employee and those that affect the company in more general terms. Indirect employee-specific costs include (1) cost of compliance with OSHA reporting; (2) wages for temporary employees to accomplish the tasks of ill or injured workers; (3) case-management costs; (4) vocational rehabilitation counseling costs; (5) case-specific litigation costs; (6) case-specific human resource or personnel costs; and (7) costs of specific accommodations required by the Americans with Disabilities Act. Indirect general costs include (1) absence of the injured or ill employee; (2) shift in activities of coworkers to accomplish the absent employee's work; (3) increased supervisor effort to cope with the absence of the employee; (4) temporary or long term absence of corporate policy possessed by the ill or injured employee; (5) start-up and training time for the replacement employee; (6) start-up and training time for the returning ill or injured employee; (7) development of a limited work position for the ill or injured worker, as appropriate; (8) reduced effectiveness of "nearby" coworkers; and (9) overtime pay. Possible impacts on competitiveness include (1) potential for reduced customer satisfaction because of employee absence; (2) greater-than-projected medical costs; (3) increased risk of illness or injury in the temporary replacement employee because of limited time for hazard or safety training or other factors; (4) increased insurance premiums; (5) increased overtime costs and increased training and retraining costs; (6) increased legal costs, including class-action defense, coordination of new policies to respond to event or prevent recurrence and related costs, and the loss of senior management time as required to respond to event; (7) reduced performance and effectiveness of the returning ill or injured person; (8) effects on labor relations, including requests for hazardous pay, new safety programs or equipment, strike potential, adverse media coverage, effect on worker morale (which also impacts productivity), requirements for increased quality control efforts, as required, for the replacement or returning employee, increased human resources and personnel department costs associated with efforts to replace the ill or injured worker, medical, industrial hygiene, and safety costs involved in the investigation of accident or exposure site, and risk-management activities involved with respect to investigation of accident or exposure site or other activities.[3]

The effectiveness of intervention programs have been discussed by Hochanadel and Conrad,[68] Melhorn,[37] and Warner et al.[69] When considering the costs related to the injured worker, Golaszewski et al[12] concluded that most prevention programs can achieve a benefit-to-cost ratio of 3.4 or more.

The employer in this study is self-insured for worker's compensation and was able to provide accurate direct costs of workers' compensation costs as defined above. By using the yearly cost of the MSD intervention program, $76,118, and using only employer-estimated savings for direct workers' compensation costs at $469,990 the first year, $678,337 the second year, $1,936,105 the third year, and $1,995,759 the fourth year, the benefit-to-cost ratio for the first year would be 6, 9 for the second year, 25 for the third year, and 26 for the fourth year. In the study presented here, the average benefit-to-cost ratio was 16.5 to 1. This fact illustrates that for every dollar spent for prevention (MSD intervention), the employer saved 16.5 dollars per year over the 4-year period, with a range of $6 to $26. If the indirect costs had been included, the results would be even more dramatic.

Conclusions

Musculoskeletal pain associated with the workplace accounts for 1.88 million injuries and illnesses in the private sector and 185,927 claims in the federal sector per year at an estimated total cost of $1.25 trillion. Although the concept of prevention of musculoskeletal pain is appealing and has been encouraged by the US government through legislated programs, it has been difficult to demonstrate successful application of such prevention programs in the workplace and the resulting benefits to the employer. In addition, some employers have been reluctant to establish workplace screening for fear of increased costs related to workers' compensation. The current MSD intervention program was designed to evaluate the impact of an integrated traditional occupational medicine clinic approach and a disease-specific individual risk-assessment instrument. Using individual risk and standardized protocols for new hires, the benefit-to-cost of the intervention program was evaluated over a 4-year period. Although the recordable incidence rate increased, the lost time case incidence rate and the lost time day severity rate decreased significantly. The correlation for benefit to the reduction in costs for the MSD invention program was statistically significant at $P < 0.01$. The benefits to the employer were substantial, resulting in a direct dollar savings of over $5 million during the first 4 years of the study.

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ORIGINAL ARTICLES

An Outcomes Study of an Occupational Medicine Intervention Program for the Reduction of Musculoskeletal Disorders and Cumulative Trauma Disorders in the Workplace **833**
J. Mark Melhorn, MD, Larry Wilkinson, MD, Peggy Gardner, PhD, W. Dale Horst, PhD, and Beryl Silkey, ScM