Journal of Occupational Rehabilitation, Vol. 15, No. 1, March 2005 (© 2005)
DOI: 10.1007/s10926-005-0871-2

Predictors of Upper Extremity Discomfort: A Longitudinal Study of Industrial and Clerical Workers

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Upper extremity discomfort associated with work activity is common with a prevalence of over 50% in many settings. This study followed a cohort of 501 active workers for an average of 5.4 years. Cases were defined as workers who were asymptomatic or had a low discomfort score of 1 or 2 at baseline testing and went on to report a discomfort score of 4 or above on a 10-point visual analog scale. This change is considered clinically significant. Controls had a low baseline discomfort score and continued to have a low discomfort rating throughout the study. The risk factors found to have the highest predictive value for identifying a person who is likely to develop a significant upper extremity discomfort rating included age over 40, a BMI over 28, a complaint of baseline discomfort, the severity of the baseline discomfort rating and a job that had a high hand activity level (based upon hand repetition and force). The risk profile identified both ergonomic and personal health factors as risks and both factors may be amenable to prevention strategies.

KEY WORDS: pain; occupational diseases; logistic regression; musculoskeletal diseases.

INTRODUCTION

Pain or discomfort is one of the primary reasons that an individual worker goes to seek medical attention. A growing paradigm in medical care is to consider pain as the 5th vital sign (1). The assessment of pain is considered as important as recording the patient's temperature or blood pressure. The typical discomfort measurement tool is the use of a 10-point scale of pain intensity with 1 representing no pain and 10 representing the worst pain imaginable. Using this framework several hospital systems have identified pain at a level of 4 or above as a serious health issue and one that warrants an in-depth assessment of the causes and also requires intervention (1,2). Although individuals have varying

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degrees of pain tolerance and not all pain reported as 4/10 is the same, it is reasonable to assume that a clinically significant musculoskeletal problem exists if the pain level is 4 or above (2).

In the workplace, the majority of workers have some episode of pain or discomfort that is associated with the work activities. Most of the complaints are mild (usually <4 on the pain scale) and do not prompt a visit to a health care provider.

The International Association for the Study of Pain defines pain as 'an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage.' We have come to understand that pain perception is a complex phenomenon and is influenced by many factors. As such it is not a direct indication of a musculoskeletal disorder but can be used as a marker for injury as long as we understand that they are not one and the same. Although work related musculoskeletal injuries have been documented for centuries, there is still some controversy regarding the nature of the injuries and whether work activities are the primary cause. Despite these controversies, the prevalence of pain and discomfort in the workplace is staggering. Several studies have demonstrated prevalence of repeated complaints of musculoskeletal discomfort complaints of over 65% in several work settings ranging from clerical to industrial workers (3).

There is a large body of literature documenting the prevalence of upper extremity musculoskeletal disorders in relation to work activity. The National Institute for Occupational Safety and Health (NIOSH) reviewed the existing epidemiologic literature in 1997 and concluded that there was a strong association between workplace physical factors and musculoskeletal disorders (4). There was also an enormous cost associated with these musculoskeletal disorders and the primary presenting feature of all these disorders was pain.

Older workers are known to be at higher risk for nerve compression injuries and shoulder tendonitis (5,6). As the body ages, there are cumulative injuries that lead to some of the most common musculoskeletal disorders. Carpal tunnel syndrome (CTS) is the best example. Histological studies have demonstrated that with aging, there is a thickening of the synovium at the edges of the carpal canal that may lead to impingement of the median nerve within the carpal tunnel (7). Several other epidemiologic studies have also demonstrated age as an independent risk factor for CTS (5,8). In regards to tendonitis, the body's ability to repair damage is impaired as part of the aging process and in the work setting, the repeated microtraumas associated with repeated exertions may exceed the body's ability to repair itself and lead to tendonitis; this is most prominent with rotator cuff injuries that are quite rare in persons under 40 years of age.

In addition, gender has been identified as a risk factor for upper extremity nerve entrapments and tendonitis. Women are at greater risk for carpal tunnel syndrome (5,9) and for upper extremity tendonitis (10). Whether this is related to a higher likelihood of reporting compared to men or due to greater physical demands in relationship to their functional capacity is not well established.

Most musculoskeletal disorders present with pain or discomfort as the initial complaint. The use of symptom surveys in the workplace has grown dramatically in the last decade. Many industrial hygiene and occupational medicine providers see the symptom survey as a mechanism for identifying workers with mild symptoms in hopes of preventing a more serious musculoskeletal disorder in the future and/or to identify jobs that place workers at high risk of injury and thus identify which jobs need ergonomic modification.

In this longitudinal study, we sought to analyze what was predictive of new onset of significant pain or discomfort over time. We hypothesized that:

- Workers with higher ergonomic risk factors would be more likely to develop significant discomfort over time.
- Older workers would be more likely to develop new discomfort.
- Women would be more likely to report new discomfort compared to men.

METHODS

This was a longitudinal study of workers from four industrial and three clerical work sites. Of the 985 subjects who participated in a baseline study, 501 (51%) were screened an average of 5.4 years later. Excluding subjects that could not be contacted, there was a 74% participation rate at follow-up. Eighteen percent ($n = 179$) declined to participate and 31% ($n = 305$) of the original 985 could not be contacted.

The baseline demographics of both participants and non-participants in the follow-up screening are presented in Table I. Non-participants did not differ with regards to BMI, hand dominance, repetition level, median mononeuropathy, or prevalence of upper extremity tendonitis compared to responders. Responders were significantly older than non-responders (39.1 versus 35.8, $p < 0.01$), were more likely to be female (71% versus 62%, $p = 0.004$), had a significantly higher percentage reporting neck/shoulder symptoms (49% versus 43%, $p = 0.04$), and were more likely to have had a diagnosis of CTS at baseline (6% versus 3%, $p = 0.01$).

Subjects were eligible to participate if they were in the same job, had changed jobs, or retired. All subjects underwent a directed physical examination of the upper extremities and completed a symptom questionnaire. Electrodiagnostic testing of the median and ulnar sensory nerves was also performed according to the techniques described by Kimura (11). All jobs were assessed and rated for ergonomic exposures at baseline (12). Each job was rated according to the American Congress of Governmental Industrial Hygienists' (ACGIH) threshold limit values (TLV) for hand activity level based upon the hand repetition level and the normalized peak force (13). Psychosocial variables were assessed using a questionnaire

Table I. Comparison of Baseline Results of Responders vs. Non-participants to Recruitment at Time 2 (5 Year Follow-up), Mean (SD)

	Responders $n = 501$	All non-responders $n = 484$	p
Age	39.1 (9.9) Range 19–69	35.8 (10.5) Range 19–65	0.00
BMI	28.3 (6.6)	27.6 (6.5)	0.09
Baseline repetition level	5.8 (1.9)	5.9 (1.9)	0.49
Gender (% female)	71	62	0.00
Hand dominance (right-hand dominant, %)	10	11	0.51
Median mononeuropathy ($\geq$0.5 msec) (%)	18	15	0.23
Diabetes (%)	2.2	2.7	0.61
Rheumatoid Arthritis (%)	2.4	1.2	0.18
Current neck/shoulder symptoms (%)	49	43	0.04
Current elbow/forearm symptoms (%)	31	26	0.06
Current wrist/hand/finger symptoms (%)	55	50	0.12
Tendonitis in the upper extremity (%)	16	15	0.71
CTS (%)	6	3	0.01

based on the one developed by Karasek (14). The areas assessed included estimates of skill discretion, job insecurity, perceived stress and job satisfaction based on the decision latitude of the worker and the psychological demands placed upon the worker. Each worker was weighed and measured for height to calculate the body mass index (BMI, kg/m^2).

From the original cohort, we identified all workers who had a pain score of 2 or below at the baseline screening on our 0–10 discomfort rating scale. This was a global discomfort score of their worst regional discomfort rating from any upper extremity region. If they complained of discomfort of 3 or greater in any upper extremity region, they were excluded from this analysis. The discomfort had to have been present for a week or more or occurred on 3 or more episodes within the last year.

This subset of workers was divided into two groups based upon their global discomfort rating at follow-up. Incident cases were defined as those workers who had progression of their discomfort and had a rating of 4 or greater at follow-up and those workers who maintained a discomfort rating of 2 or below at follow-up were considered controls for this analysis. Any worker who reported a discomfort score of 3 at follow-up was dropped from the analysis.

Statistics

We evaluated which demographic, ergonomic, psychosocial variables and prior medical problems at baseline would be predictive of incident cases. A subset of the study cohort with 'No Significant Discomfort' was selected for analysis. The dependent variable was whether these workers developed into 'Incident Cases.' The independent variables included demographic variables, i.e. age, gender, medical history, obesity, smoking history, and exercise levels as well as all ergonomic posture and force variables and the psychosocial work related variables of skill discretion decision authority, coworker support, job insecurity, job satisfaction and perceived stress. Electrophysiologic variables were also included as independent variables. Initially a univariate analysis was done and this was followed by logistic regression modeling to determine the most predictive model for determining incident cases from the baseline data. A secondary analysis was run to determine if changes in the job may have also influenced incident cases.

RESULTS

There were 46 incident cases identified, i.e. workers who had minimal symptoms at baseline and later developed significant upper extremity discomfort. There were 261 workers identified as controls, i.e. workers who had minimal symptoms and their symptoms remained minimal when documented at the beginning and at the end of the study. The average age of this cohort was 38.7 years and 64% were female. Table II includes the demographic characteristics of the cases and control subjects in this cohort. The table also includes some symptom results (including hand diagram results) and electrophysiologic measures of the median and ulnar nerves. There were no differences between the cases and controls in terms of age, gender, medical co-morbidities, exercise level and most of the psychosocial variables.

The cases and control groups did differ in terms of several demographic, symptoms and electrophysiologic measures. The cases had a higher BMI (30.7 versus 28.2, $p = 0.02$),

Table II. Comparison of Global Discomfort Rating Changes Between Subgroups

Risk factors	Change in global discomfort rating during the study (0,1,2 ⟶ ≥4) cases (*N*)	Change in global discomfort crating during the study (0,1,2, ⟶ 0,1,2) controls (*N*)	*p*
Demographic factors			
AGE	40.43 (46)	38.58 (265)	0.24
BMI	30.7 (46)	28.2 (261)	0.02
Gender (% female)	69.57 (46)	63.4 (265)	0.42
Retired (%)	4.35 (46)	10.19 (265)	0.21
Job change (%)	52.17 (46)	58.17 (263)	0.45
Clerical (%)	56.52 (46)	58.49 (265)	0.8
Regional symptoms			
Wrist/hand/finger (%)	69.57 (46)	37.36 (265)	<0.01
Neck/shoulder (%)	54.35 (46)	33.96 (265)	0.01
Elbow/forearm (%)	41.3 (46)	21.51 (265)	<0.01
Medical co-morbidities			
Diabetes (%)	0 (46)	2.65 (264)	0.59
Rheumatoid Arthritis (%)	2.17 (46)	2.28 (263)	0.96
Exercise (%)	72 (25)	58.39 (161)	0.19
Smoke (%)	52.17 (46)	36.6 (265)	0.05
Psychosocial variables			
Skill discretion	24.3 (45)	25.69 (259)	0.24
Decision authority	26.13 (45)	26.5 (262)	0.79
Created	6.6 (45)	6.98 (262)	0.26
Coworker support	11.58 (36)	11.74 (197)	0.58
Supervisor support	10.2 (44)	11.36 (250)	0.01
Job insecurity	4.22 (36)	4.44 (196)	0.43
Job satisfaction	0.29 (46)	0.29 (259)	0.98
Perceived stress	24.68 (35)	23.2 (200)	0.27
Electrophysiologic factors			
Median mononeuropathy ≥0.5 msec (%)	30.34 (46)	19.25 (265)	0.08
Abnormal hand diagram (%)	43.48 (46)	16.23 (265)	<0.01
Median ulnar peak latency difference (dominant side)	0.39 (46)	0.18 (264)	0.01

were more likely to have reported some regional upper extremity symptom at baseline (these symptoms were rated as a 1 or 2 on a discomfort scale up to 10), and reported a lower level of supervisor support in their job. Cases were more likely to have slowing of the median nerve based upon a comparison of the median sensory evoked response to the ulnar sensory evoked response. Additionally, more cases had a hand diagram score that was suggestive of carpal tunnel syndrome (43.5% versus 16.2%, $p < 0.001$).

The ergonomic ratings are presented for the case and control groups in Table III. The hand threshold limit value (TLV) rating (an interaction of peak force and hand repetition level) was higher among the cases. Sixty four percent of cases had a borderline or high risk rating compared to only 39% of workers among the control group, $p = 0.01$. The peak hand forces were higher among cases (3.4 versus 2.9, $p = .04$) and the average hand forces followed the same trend. Peak finger postures as well as peak wrist postures were demonstrated to be higher among cases and peak shoulder posture followed a similar trend.

A logistic regression model demonstrated many similar findings but also demonstrated some new relationships. (see Table IV) Obesity and a baseline complaint of a hand/wrist/finger problem were associated with an increase in discomfort over time. A worker with a BMI over 28 (a BMI of 29 is considered obese) was almost two times more

Table III. Ergonomic Risk Factors and Global Discomfort Rating Changes During the Study Among Cases and Controls

	Cases (n) (0,1,2 $\longrightarrow \geq 4$)	Controls (n) (0,1,2, $\longrightarrow$ 0,1,2)	p
Abnormal HAND TLV[a] rating (%)	64.29 (28)	39.19 (148)	0.01
Hand repetition	5.81 (46)	5.51 (258)	0.33
Peak force	3.36 (46)	2.92 (257)	0.04
Average force	1.09 (36)	0.94 (198)	<0.01
Peak finger contact stress	2.87 (36)	2.53 (198)	0.18
Average finger contact stress	1.25 (46)	1.13 (258)	0.24
Peak wrist contact stress	2.4 (36)	2.26 (198)	0.48
Average wrist contact stress	1.08 (46)	1.02 (258)	0.49
Peak forearm contact stress	1.03 (36)	1.09 (198)	0.53
Average forearm contact stress	0.48 (36)	0.5 (198)	0.73
Peak elbow contact stress	0.28 (36)	0.32 (198)	0.60
Average elbow contact stress	0.02 (36)	0.015 (198)	0.75
Peak finger posture	6.72 (36)	6.38 (198)	0.04
Average finger posture	4.21 (36)	4.23 (198)	0.96
Peak wrist posture	5.54 (36)	5.03 (198)	0.01
Average wrist posture	2.57 (46)	2.31 (258)	0.02
Peak forearm posture	7.17 (36)	7.01 (198)	0.20
Average forearm posture	4.37 (46)	4.49 (258)	0.74
Peak elbow posture	4.96 (36)	4.78 (198)	0.33
Average elbow posture	3.45 (36)	3.23 (198)	0.17
Peak shoulder posture	5.01 (36)	4.45 (198)	0.06
Average shoulder posture	2.57 (46)	2.46 (258)	0.26

[a]TLV: Threshold limit value above the proposed action limit.

likely to develop more upper extremity discomfort compared to thinner workers. If the worker had an initial complaint of a hand/wrist/finger problem (even though it was rated as a 1 or 2 at baseline) they were three times more likely to develop progression of their symptoms compared to a totally asymptomatic group of workers. If the worker was in a job where the combination of hand repetition and peak hand force placed them in the TLV of borderline or high risk, they were twice as likely to develop more discomfort over time compared to the workers with a 'safe' TLV for these ergonomic factors. Age over 40 was a new risk factor identified by the logistic regression. Workers over 40 were 2.5 times more likely to develop increased discomfort compared to younger workers. The model was highly significant with a pseudo R^2 of .14.

Additional logistic regression models were explored using a subset of only active workers and another with incident cases defined as a change in two points or more on their global pain score compared to baseline. Neither of these models differed significantly from the results reported for the model reported earlier.

Table IV. Logistic Regression Model for Incident Cases of New Upper Extremity Discomfort, Odds Ratio and 95% CI

Variable	Odds ratio	p value	95% CI
Age >40	2.51	0.01	1.22, 5.14
BMI >28	1.89	0.07	0.94, 3.79
Worst discomfort at baseline	1.59	0.06	0.98, 2.58
History of wrist/hand/finger discomfort	3.14	0.005	1.41, 6.99
Hand TLV above the proposed action limit	2.14	0.05	1.01, 4.54

$N = 293$, p value for model < 0.001, Pseudo $R^2 = 0.14$.

DISCUSSION

Our original hypothesis that ergonomic risk factors would be predictive of future upper extremity discomfort was supported by the finding that the borderline and unacceptable TLV categories did help predict future discomfort. The TLV is a theoretical assessment based upon hand repetition and peak hand forces and defines a safe zone, a borderline zone and an unacceptable zone when these two factors are graphically represented. Workers with a baseline job that was in the borderline or unacceptable zones were twice as likely to develop more discomfort over time. The other ergonomic variables such as shoulder, elbow, wrist and hand postures and contact stress were not significant in the logistic model although the finger, wrist and shoulder postures were all significant in the univariate analysis.

The hypothesis that age would influence the development of more discomfort was also supported by the logistic regression modeling. In the univariate analysis, incident cases were older but did not reach a level of significance. Aging is known to be associated with slower physiologic recovery from injury and thus it is not surprising that workers over 40 were 2.5 times as likely to develop significant discomfort over time compared to younger workers. Age was strongly associated with years of tenure on the job.

Although women tend to be more forthcoming in disclosing musculoskeletal complaints in the general population, gender was not a significant factor in the logistic or univariate analysis. Active workers may not be representative of the general population. The type of job (clerical versus industrial) did not influence the model either. There were a higher percentage of women in the clerical jobs but neither gender or job classification had a significant impact on the model.

Obesity as measured by BMI was a significant factor influencing the progression of discomfort among these workers. The obese worker was twice as likely to develop significant discomfort over time compared to the thinner workers. Obesity has been related to carpal tunnel syndrome in other studies as well as in this present study and this may be a co-linear factor in the analysis.

Workers with some minor complaint of wrist/hand/finger discomfort (rated as a 1 or 2 on a 10-point scale) were three times more likely to develop significant discomfort over time. This is somewhat intuitive but strongly supports active surveillance in the work setting. This could be a mechanism of secondary prevention for workers who are identified with minor upper extremity problems. These workers could be provided with early intervention from a medical or ergonomic perspective.

The limitations of the study include methodological issues such as limited surveillance of both subjects and jobs, recruitment of subjects, and modeling of the exposure-response relationships. Follow-up was performed after 5 years and many intervening events, both increased discomfort and treatment for that discomfort, could have occurred and not been recognized with the current study design. The study was not designed as a continuous surveillance study. The study population was initially chosen as a cross-sectional study design and later additional funding was obtained to translate the study into a longitudinal study. The timing of the funding and the amount of funding limited the amount of active surveillance that could occur. The loss of half of the original sample also raises the issue of a 'healthy worker' effect and may under estimate the extent of the problem.

CONCLUSION

Although discomfort ratings are not a specific diagnosis, it is a valuable marker for upper extremity musculoskeletal disorders. A change in discomfort rating is highly correlated with specific disorders and is typically the presenting symptom. A change from no pain or minimal pain to moderate or severe pain (pain $\geq 4/10$) is a common model for further assessment of pain and intervention to relieve the pain in many hospital systems. Pain is commonly referred to as the 5th vital sign and as such can be a valuable tool in the industrial setting as well.

The presence of minimal pain was a risk factor for the development of more significant pain and can be used to identify workers at risk and could be used for focused intervention or prevention strategies. Obesity and older age were also noted as independent risk factors for the development of significant pain. The classification of the work as ‘unacceptable’ based upon the TLV rating was evidence that the ergonomic stressors of the job, specifically the combination of repetition and force, was another risk factor and would argue for reassessment of these type of jobs in the workplace. Surveillance for these risk factors may enhance a prevention or intervention program in the workplace.

ACKNOWLEDGMENT

Support for this research is provided by the National Institute on Disability and Rehabilitation Research of the United States Department of Education, Grant #H133E980007, “Rehabilitation Engineering Research Center.” The opinions contained in this publication are those of the grantee and do not necessarily reflect those of the United States Department of Education.

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