PROSPECTIVE STUDY OF UPPER EXTREMITY MUSCULOSKELETAL DISORDERS
Grant Number U01OH07316

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SHARP
Safety & Health Assessment & Research for Prevention

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ABSTRACT

This epidemiologic study of upper extremity musculoskeletal disorders in manufacturing and health care industries collected individual demographic, health, psychosocial, work organizational and physical load exposure information among 733 permanent full-time workers in 12 different workplaces in Western Washington.

As participants were diagnosed with a clinical outcome or leave the workplace, they were removed from the cohort. These participants were replaced with newly hired workers quarterly (resulting in approximately 1000 total participants) for determination of disease incidence in the workplace. All participants entering the cohort were given a clinical exam (physical examination and nerve conduction testing) and complete all study. The participants were also questioned briefly to determine current job and health status, with symptomatic workers examined for clinical morbidity outcomes. All workers were initially classified by job into one of six different exposure levels based on hand force and repetition rate determined from observational assessment and force measurement. Detailed task analysis and exposure assessment using task-based video analysis and force estimation was conducted on all participants representing each of the exposure levels in the two work environments.

Worker health and exposure was assessed every four months for up to three years. Individuals doing the “same” job often had different exposures, indicating the value of individual exposure assessment in these types of studies. Prevalent, persistent and incident cases of tension neck syndrome, rotator cuff tendinitis, lateral and medial epicondylitis and carpal tunnel syndrome were identified. Multivariate analysis identified slightly different factors associated with each of these clinical conditions at baseline and for incident cases over the course of three years.

HIGHLIGHTS/SIGNIFICANT FINDINGS

Important findings from the multivariate analyses include:
Tension Neck Syndrome

- Age was of borderline significance in the baseline prevalence analysis and was a significant predictor in the prospective analysis. Neither gender or BMI were significant
- Being in a psychosocially active job (high demands-high control) was protective compared to being in a low strain job in the baseline analysis but was not significant in the prospective analysis
- Movement (neck rotation, frequent arm movement) appeared to be protective in the baseline analysis whereas maintaining the same shoulder rotation more than 48% of the time significantly increased risk in the prospective analysis.

Rotator Cuff Tendinitis

- Age was of borderline significance in the baseline prevalence analysis and was a significant predictor in the prospective analysis. Gender was not significant in either analysis. BMI was significant in the baseline analysis but not in the prospective analysis
- Having another upper extremity MSD increased risk in both analyses
- No psychosocial factors were identified
- The duration of upper arm flexion/extension were associated with increased risk in both the baseline and prospective analyses
- There was an exposure-response relationship observed between increased duration of duty cycle and rotator cuff tendinitis at baseline.
- The small number of incident cases decreased our ability to identify other significant predictors in the prospective analysis.

Lateral Epicondylitis

- Increasing age was marginally significant in both the baseline and prospective analyses whereas female gender was significant in the baseline but not the prospective analysis. BMI was not significant in either analysis
- Having another upper extremity MSD significantly increased risk in both analyses
- Being “non-white” as well as having high social support were protective in the baseline analysis but non-significant in the prospective analysis
- In the baseline analysis, there was a significant exposure-response relationship with increasing frequency of high forces and with percent of time in forearm rotation more than 45 degrees. In the prospective analysis, there was increased risk of lateral epicondylitis with duration of upper arm rotation (exposure response) and with frequency of shoulder movements.

Carpal Tunnel Syndrome

- Increasing age and BMI were associated with carpal tunnel syndrome in both the baseline and prospective analyses whereas gender was not significant in either analysis
- There was an exposure-response relationship with increasing frequency of high force and duration of wrist flexion-extension in the baseline analyses. In the prospective analysis, percent of duty cycle spent in forceful exertions was a predictor for CTS. Thus either frequency or duration of forceful exertions appears to be strong predictors for CTS.

Loss to follow-up due largely to an economic downturn reduced our ability to test a variety of exposures prospectively. Work with the WMSD consortium identified areas where data could be combined at some point if the will and resources were available.

TRANSLATION OF FINDINGS

The promising findings of our study suggest the importance of supporting expansion where possible. This study supports the need for testing revised risk assessment models for practitioners.

OUTCOMES/RELEVANCE/IMPACT

Reducing and controlling workplace illnesses and hazards have been a high priority for industries and occupational health and safety organizations across the country. The research completed in this study allowed the more precise estimation of exposure response relationships which could be used to develop more effective prevention efforts.

This research prospectively considered individual and psychosocial factors, and observational assessments at the individual level, which allowed the delineation of the contributions of work-related psychosocial, work-related physical load and individual factors in the development of UEMSDs. It was shown that the presence of the workload factors of high hand force, awkward postures of the neck, shoulder, elbow, hand/wrist and repetitiveness of the work performed was associated with the prevalence and incidence of upper extremity work-related musculoskeletal disorders. An exposure-response relationship was also evident - an increase in the frequency, duration or intensity (amplitude) of the exposures was shown to increase the upper extremity musculoskeletal disorders.

SCIENTIFIC REPORT

PROSPECTIVE STUDY OF UPPER EXTREMITY MUSCULOSKELETAL DISORDERS
Grant Number U01OH07316-05

September 30, 2000 – September 29, 2006

A. EXECUTIVE SUMMARY

This epidemiologic study of upper extremity musculoskeletal disorders in manufacturing and health care industries collected individual demographic, health, psychosocial, work organizational and physical load exposure information among 733 permanent full-time workers in 12 different workplaces in Western Washington. Worker health and exposure was assessed every four months for up to three years. Individuals doing the "same" job often had different exposures, indicating the value of individual exposure assessment in these types of studies. Prevalent, persistent and incident cases of carpal tunnel syndrome, lateral and medial epicondylitis, rotator cuff tendinitis, and tension neck syndrome were identified. Multivariate analysis identified slightly different factors associated with each of these clinical conditions at baseline and for incident cases over the course of three years.

Important findings from the multivariate analyses include:

Carpal Tunnel Syndrome

- Increasing age and BMI were associated with carpal tunnel syndrome in both the baseline and prospective analyses whereas gender was not significant in either analysis
- There was an exposure-response relationship with increasing frequency of forceful exertion and duration of wrist flexion-extension in the baseline analyses. In the prospective analysis, percent of duty cycle spent in forceful exertions was a predictor for CTS. Thus either frequency or duration of forceful exertions appears to be strong predictors for CTS.

Lateral Epicondylitis

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- In the baseline analysis, there was a significant exposure-response relationship with increasing frequency of forceful exertion and with percent of time in forearm supination more than 45 degrees. In the prospective analysis, there was increased risk of lateral epicondylitis with duration of upper arm supination (exposure response) and with frequency of shoulder movements.

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Tension Neck Syndrome

- Age was of borderline significance in the baseline prevalence analysis and was a significant predictor in the prospective analysis. Neither gender or BMI were significant
- Being in a psychosocially active job (high demands-high control) was protective compared to being in a low strain job in the baseline analysis but was not significant in the prospective analysis
- Movement (neck rotation, frequent arm movement) appeared to be protective in the baseline analysis whereas maintaining the same shoulder rotation more than 48% of the time significantly increased risk in the prospective analysis.

Loss to follow-up due largely to an economic downturn reduced our ability to test a variety of exposures prospectively. Work with the WMSD consortium identified areas where data could be combined at some point if the will and resources were available. The promising findings of our study suggest the importance of supporting expansion where possible. This study supports the need for testing revised risk assessment models for practitioners.

B. SPECIFIC AIMS

The purposes of this prospective study were to follow a cohort of workers in manufacturing and health care to quantify the relationship between work-related physical load factors and the development of non-traumatic soft tissue musculoskeletal disorders of the upper extremities, while accounting for individual factors as well as psychosocial factors.

Specifically, we intended to:

1. Compare the incidence and persistence of Upper Extremity Musculoskeletal Disorders (UEMSDs) as a function of individual, physical load and psychosocial factors
2. Recruit approximately 1,000 workers, who are on jobs with different hand force and hand activity levels.
3. Conduct detailed physical load exposure assessments at entry into the study, and when the job changes
4. Conduct physical examinations, electrodiagnostic tests, health histories and psychosocial questionnaires at baseline and repeat questionnaire surveys, electrodiagnostic tests and other hand function measurements annually thereafter
5. Collect quarterly symptoms questionnaire and job change information (re-examine newly symptomatic employees)
6. Compare observed exposures using different assessment methods.

We hypothesized that the presence of the workload factors of hand force, awkward postures of the neck, shoulder, forearm, hands and wrists and repetitiveness of the work performed will be associated with the prevalence and incidence of upper extremity work-related musculoskeletal disorders. Further, we hypothesized that there would be exposure-response relationships: as the frequency, duration or intensity (amplitude) of the exposures increased, there would be an increase in upper extremity musculoskeletal disorders (UEMSDs)

C. BACKGROUND AND SIGNIFICANCE

Work-related musculoskeletal disorders (WMSDs) of the neck, back and upper extremity represent the most frequent and costly conditions in the Washington State workers compensation system (Bonauto et al, 2006). In Washington State, there are approximately 20,000 workers compensation claims accepted every year for work-related UEMSDs (Silverstein et al, 2006). The average claim cost for UEMSDs was $11,411 (median ($833) with an average of 72 lost workdays (median 72 days). This research addresses the NORA priority of upper extremity disorders in the workplace and is applicable to all industry sectors. Specific examples of UEMSDs include carpal tunnel syndrome, tendinitis of the hand/wrist, epicondylitis and rotator cuff syndrome. Reducing workplace illnesses and hazards has been the first priority of the Washington State Department of Labor and Industries. Research to more precisely estimate exposure response relationships will result in more effective targeting of prevention efforts. Prospective study of musculoskeletal disorders at the workplace provides us with the most important information in accomplishing our goals.

There have been a number of peer-reviewed epidemiological studies that have quantitatively estimated risk of UEMSDs related to different levels of exposure to physical workload factors based on duration, frequency and /or intensity of exposure (NAS 2001NRC 1999). Typically three categories of risk factors have been identified and associated with the development of UEMSDs: awkward postures, high hand forces and high repetition. Specific postures and the duration of time in them have been associated with UEMSDs in a wide variety of industries. While these studies have increased our knowledge of the relationship between certain physical load factors and UEMSDs, they have used different methods, had limited exposure levels. Some did not consider individual and psychosocial factors in the analysis. Few were prospective in nature and very few of these included both direct health and observational exposure assessment at the individual level.

The interplay between work-related psychosocial, work-related physical load and individual factors requires further research to delineate the contributions of each under different circumstances. Figure M1, adapted from the NRC-IOM report on musculoskeletal disorders (NRC-IOM 2001) illustrates a proposed model of work-related musculoskeletal disorder and illness development incorporating psychosocial risk factor pathways with job-related and individual factors. Without precise and valid measurements of physical risk factors and health outcomes it is difficult to obtain accurate estimates of the contribution of any of these pathways to outcome development.

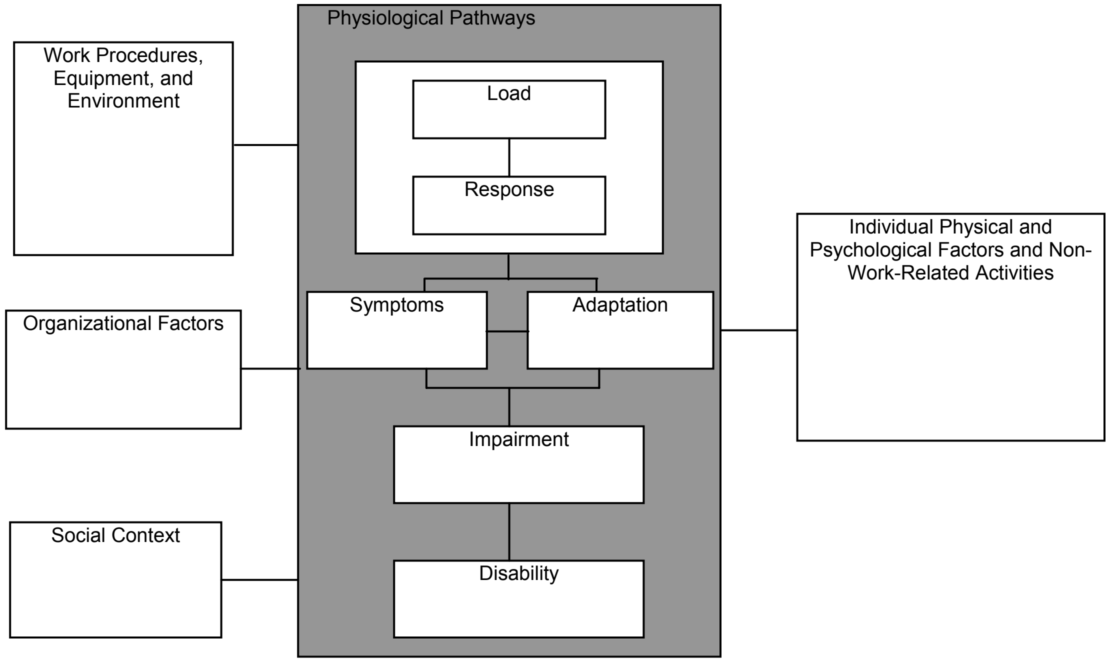

Figure M1. A proposed model of factors affecting the development of musculoskeletal injuries and illnesses (adapted from NRC-IOM, 2001).

D. STUDY DESIGN AND METHODS

Study Design

We conducted health, psychosocial and exposure assessments from 733 active workers at baseline from three health care and nine manufacturing sites in Western Washington. We conducted three additional annual visits where complete health data were collected and exposure assessments collected if there were any job changes. We also conducted interim (every four months) visits to capture changes in health (excluding electrodiagnostic testing) and exposure between annual visits (Table M1).

Table M1. Study Variables Collected by Collection Period and Type

Exposure	Variable	Collection Period			Continuous	Categorical	Dichotomous
		4 mo interim	**Yearly**	**Baseline Only unless job change**			
Direct Measurements	force gauge			X	X		
	weights of objects			X	X		
Observational Measurements	Duty cycle			X	X		
	Grip Type			X		X	
	Hand Force			X	X[a]		
	Hand Repetition			X	X[b]		
	Hand/wrist Posture			X	X[c]		
	Forearm Repetition			X	X[d]		
	Forearm Posture			X	X[c]		
	Upper Arm Repetition			X	X[d]		
	Upper Arm Posture			X	X[c]		
	Neck Repetition			X	X[d]		
	Neck Posture			X	X[c]		
	Speed of hand motion			X		X	
	Estimated vibration dose			X	X		
	HAL			X	X		
	Strain Index			X	X		
Questionnaire	Psychological Demands		X			X	
	Job Control		X			X	
	Supervisor Support		X			X	
	Job Satisfaction		X			X	
	Peer Support		X			X	
	SF 12		X			X	
	Quick DASH	X if symptomatic	X if symptomatic		X		
OUTCOME							
Brief Administered Questionnaire	Upper Extremity Symptoms	X					X
	Upper Extremity Severity	X				X	
	Change in Exposure	X					X
Full Administered Questionnaire	Upper Extremity Symptoms		X				X
	Upper Extremity Severity		X			X	
Physical Exam	Clinical Diagnosis	X if symptomatic	X	X			X
	Nerve Conduction Velocity	X if symptomatic	X		X		
	Grip and pinch force		X		X		
Other	Workers Comp Claims		X				X
	Unemployment Benefits		X				X
COVARIATES	Site			X		X	
	Industry			X			X
	Age			X	X		
	Gender			X		X	
	Height & Weight		X		X		
	Smoking		X			X	
	Previous Injury			X			X
	Other Health Problems		X				X
	Time in Industry		X		X		
	Dependent care		X				X
	Drive time		X		X		
	Hobbies/2nd Jobs		X				X

[a] Variable continuous when directly measured, and as normalized peak force for HAL; ordinal for the Strain Index
[b] HAL ordinal, changes between postural categories per time unit continuous
[c] Postural angles categorical, duration of postures continuous
[d] Continuous for change of postural categories per time unit

Site, Job, and Subject Selection and Retention

We sent letters to all manufacturing worksites in Western Washington with more than 200 employees excluding industries where we have other types of studies going on. A number of sites contacted us to participate. In the service sector, we wanted to limit our activities to hospitals and related services, excluding jobs where there was routine patient contact due to our videotaping requirements.

Participating companies had to have jobs with a minimum of 30 full-time workers in at least three different hand/force activity exposure levels, Figure M2. Site walkthroughs were conducted at potential participating sites where ergonomists used a data collection form based on the ACGIH Hand Activity Level TLV (ACGIH 2001). Peak hand force were be classified as either low or high which correspond to TLV levels of 0-4 and 5-10 on the 0-10 force scale. Hand activity levels, or repetition, were classified into low, medium, or high. Observations of three workers at each of the potentially selected job types were used for this determination. No direct measurement was performed at this time. Because individual exposure assessments were to be conducted during study visits, we did not need to have multiple people in exactly the same job. We excluded jobs where the workers were largely mobile (e.g. fork-truck drivers) or had more than 4 tasks or rotated between jobs.

		Repetition		
		Low (0-3)	Medium (4-6)	High (7-10)
Force	Low (0-4)	Level 1	Level 2	Level 3
	High (5-10)	Level 4	Level 5	Level 6

Figure M2. Exposure categories based on peak hand force and wrist repetition rate.

In the health care sector, we had participation by two hospitals and one health research facility. In the manufacturing sector, we had participation by saw and plywood mills (2), electronics, window (2), machine (3), and furniture manufacturing. Worksite retention over the course of the study was facilitated by receiving summary information about their facility compared to the overall study population and newsletters about relevant topics.

Subject recruitment methods varied. In some places, we set up tables in the cafeteria where supervisors would send employees in the job categories of interest to hear about the study and decide whether to participate. In others, individual recruitment at the job took place. In all cases, the study, time commitment, criteria and voluntary nature of participation were described. We then went over consent forms with individuals interested in participating. Consent forms were in multiple languages, as were all questionnaires and information about the study. Interpreters were present during recruitment as well. The only incentive was being off work for about an hour to participate in the examinations, knowing the results of their examinations and knowing that they were contributing to information that may improve Washington workplaces overall. No monetary incentives were provided. Study protocols were approved by the Washington State Institutional Review Board. Overall, we had participation by 68% of those eligible. This varied by site (Table M2). In most facilities, the company limited the number of employees who could participate in the study due to potential production losses. After the 5th visit to one of the window manufacturers, the employer withdrew from the study due to the amount of time participants were away from production and due to the economic recession, the electronics manufacturer cut staff by more than 60% and hired temporary workers by the end of the second year and became unavailable after the 10th visit. Other manufacturing facilities also experienced layoffs during this period but not as severely as the above two.

Table M2. Study Participation at Baseline

	ELIGIBLE	ENROLLED	%
Site 1	105	39	37%
Site 2	59	59	100%
Site 3	97	97	100%
Site 4	72	72	100%
Site 5	116	116	100%
Site 6	209	59	28%
Site 7	99	73	74%
Site 8	64	64	100%
Site 9	60	54	90%
Site 10	121	40	33%
Site 11	60	52	87%
Site 12	76	23	30%
	1138	748*	68%

*15 subjects excluded due to ineligibility

Health Assessment Methods

A detailed health history collected by interviewers, self-or assisted completion of a psychosocial questionnaire, uniform musculoskeletal physical examination conducted by trained examiners and electrodiagnostic testing of the median and ulnar nerves at the wrist were administered during work time at the participating facilities at baseline and annually. Briefer interim questionnaires were administered between annual visits (at 4 and 8 months) and if newly symptomatic or increased severity of symptoms, a focused physical examinations were conducted. Data recording instruments are provided in Appendix A.

In addition to demographic data, the health history included information about pertinent diseases (diabetes mellitus, rheumatoid arthritis, thyroid disease, etc), acute traumatic injuries, personal habits (smoking, hobbies, driving time), dependent care, musculoskeletal symptoms with body maps, and psychosocial aspects of work (job satisfaction, supervisory support, control over work).

At baseline and annual visits, for each body region (using a body map) where recurring pain or discomfort was identified (occurring more than 3 times or lasting more than one week in the previous year), more specific information is obtained including:

time of onset of symptoms
duration of symptoms
frequency of symptoms
intensity of symptoms
aggravating factors
job when symptoms were first noticed
lost or restricted time
interference with quality or productivity
treatment

For those with symptoms in the previous week, we included the general disability and work modules of the QuickDASH (Beaton et al, 2003).

The annual and interim worker questionnaire interview also inquired about duration on the current job, shift, hours and days of work, overtime schedules, the number of days off in the last week and month, changes in the previous four months in tools/equipment, parts made, workstation/area, tasks, rotation pattern, pace.

Psychosocial and Quality of Life Assessment

At baseline subjects were given a psychosocial questionnaire which included questions designed to evaluate general physical and mental health, social support, and job strain. The complete psychosocial questionnaire is available in Appendix A.

The SF-12 is a 12 item generic health survey adapted from the SF-36. The SF12 measures eight dimensions of subjective health functioning (physical functioning, role limitations, freedom from bodily pain, general health perception, vitality, social functioning and mental health). Summary scores for these eight dimensions were calculated to create a standardized physical component score (PCS12) and a standardized mental component score (MCS12) using established algorithms. (Ware, Kosinski and Keller, 1996)

Social support was assessed using questions from the Modified Work APGAR (Work, Adaptation, Partnership, Growth, Affection and Resolve) survey (Bigos et al 1991), which assesses a person's job satisfaction in relation to social support at work.

Job strain was evaluated using questions from Karasek's Job Content Questionnaire (Karasek and Theorell, 1990). Continuous scores of job demands and job control were dichotomized at the median of the sample to create high or low demand and high or low control. Job strain quadrants were also created, according to Karasek, into low strain (low demand, high control), high strain (high demand, low control), active job (high demand, high control) and passive job (low demand, low control), see figure M3.

		Control	
		Low	High
Demand	Low	Passive Job	Low Strain
	High	High Strain	Active Job

Figure M3: Karasek job strain quadrants

These instruments were translated into multiple languages. Interviewers were blinded to examination findings and exposure assessment information.

Physical Examinations

Examiners were blinded to job and health interview/questionnaire data. Exams were conducted by occupational health physicians, physical therapists or registered nurse who had gone through specific training for these exams, using videos, slides, and physician training. Electrodiagnostic studies were performed on the dominant hand of every subject at baseline. For subjects with hand symptoms, both hands were assessed. Attempts were made to warm the hands to 32^{o}C using soaking in hot water or heating pad (depending on the location of the examinations, e.g., near water).

A clinical case was dependent on symptoms being present the week of the examination and having been recurring or lasting more than one week in the previous 12 months and no traumatic onset.

The disorders under study and their diagnostic criteria are presented in Table M3.

Table M3. Disorders, pertinent symptom questions and physical examination tests, and diagnostic criteria

Disorder	**Symptom[a]**	**Clinical Test (finding)**	**Diagnostic criteria**
Cervical syndrome	Pain in the neck radiating to the upper extremity (below elbow level) OR Pain in the neck and numbness in the hand/fingers	Active head rotation (pain in upper limb) Neck compression test (pain in upper limb below elbow level)	Symptom + AND Active head rotation + OR Neck compression test +[b]
Rotator cuff syndrome	Pain in the shoulder	Resisted shoulder abduction, external rotation, and internal rotation (pain in respective tendon insertion area) Resisted elbow flexion (pain in bicipital groove) Active shoulder abduction (pain in rotator cuff region typically at 60-120° painful arc)	Symptom + AND Resisted shoulder abduction, external rotation or internal rotation + OR Resisted elbow flexion + OR Painful arc +[c]
Lateral epicondylitis	Pain in the elbow	Resisted wrist extension (pain in lateral epicondyle), Palpation of lateral epicondyle	Symptom + AND Resisted wrist extension + [c]
Medial epicondylitis	Pain in the elbow	Resisted wrist flexion (pain in medial epicondyle), Palpation of medial epicondyle	Symptom + AND Resisted wrist flexion + [c]
Cubital tunnel syndrome	Paresthesiae/numbness in the fourth or fifth finger or ulnar border of forearm	Combined elbow flexion and pressure provocation (paresthesiae in ulnar nerve distribution distal to elbow) test at cubital tunnel (paresthesiae in ulnar nerve distribution distal to elbow)	Symptom + AND Combined elbow flexion and pressure provocation + OR Tinel +[b]
Radial nerve compression	Pain in the elbow	Resisted forearm supination (pain in dorsal side of forearm (supinator muscle) Resisted middle finger extension (pain proximally in dorsal forearm)	Symptom + AND Resisted forearm supination + OR Resisted middle finger extension +[b]
Extensor peritendinitis/ tenosynovitis of the forearm/wrist	Pain in dorsal forearm-wrist	Resisted extension of the fingers (pain in tendon or muscle-tendon junction area) Palpation of tendon-paratenon area during active flexion extension movement (palpable crepitus) Inspection of tendon-paratenon area (visible swelling of tendon sheaths or paratenon area)	Symptom + AND Resisted extension + OR Crepitus palpable OR Visible swelling[b]
Disorder	**Symptom[a]**	**Clinical Test (finding)**	**Diagnostic criteria**
Flexor peritendinitis/ tenosynovitis of the	Pain in volar forearm-wrist	Resisted flexion of the fingers (pain in tendon or muscle-tendon	Symptom + AND

forearm/wrist		junction area) Palpation of tendon-paratenon area during active flexion extension movement (palpable crepitus) Inspection of tendon-paratenon area (visible swelling of tendon sheaths or paratenon area)	Resisted flexion + OR Crepitus palpable OR Visible swelling[b]
De Quervains stenosing tenosynovitis	Wrist pain	Finkelstein's test (pain at long abductor and short extensor tendon of the thumb)	Symptom + AND Finkelstein +[b]
Carpal tunnel syndrome	Pain or paresthesia in median innervated area (hand diagram)	Tinel (paresthesiae distal to carpal tunnel area) Flexion compression test (paresthesiae in the median area within 30 seconds) Sensitivity to touch (decreased in the median area) Electrodiagnostic studies (EDS, see study proposal for details)	1. Case definition including EDS: At least possible hand diagram AND EDS + (meeting criteria A AND B OR C)[d] 2. Case definition without EDS: Classic or probable hand diagram AND Tinel + OR Flexion compression test + OR Decreased sensitivity to touch [d]
Guyon canal syndrome	Paresthesiae or pain in the palm and palmar side of 4th and 5th finger	Tinel at Guyon's Canal (Paresthesiae or hyperestehesiae distally in the ulnar innervated area)	Symptom + AND Tinel +[b]
Painful carpal ganglion	Wrist pain	Inspection of dorsal and volar wrist ganglia (observed or palpated)	Symptom + AND Ganglion observable or palpable
Trigger finger	Snapping of finger or pain	Palpation of nodes in flexor tendons of fingers at MCP joints (palpable node) Palpation of fingers in flexion extension movement of the MSP joint (palpable snapping of node)	Symptom + AND Palpable node OR Snapping of node
Osteoarthrosis of carpo-metacarpal joint of the thumb	Pain in the base of thumb	CMC grind test (pain in CMC I joint)	Symptom + AND CMC Grind Test +
Osteoarthrosis of distal upper extremity joints	Pain in distal interphalangeal joints	Inspection of Heberden's nodes	Symptom + AND Heberden's nodes observed

[a]For the symptoms to fulfill the criteria, they have to have been present for the last 7 days and of at least moderate intensity
[b] Criteria modified from Sluiter et al. (2001)
[c] Criteria according to Sluiter et al. (2001) except duration of symptoms
[d] Criteria according to Rempel et al. (1998)

While the above definitions were used in the study, We had insufficient numbers of cases in a number of the diagnostic categories to include them in separate analyses. We had sufficient numbers of cases for four clinical case definitions to be used in statistical modeling: Tension neck syndrome, rotator cuff tendinitis, lateral epicondylitis and carpal tunnel syndrome. Final definitions are included below.

General definition of clinical cases

A clinical case has to meet the following three criteria:

- Symptoms (problems of neck, shoulder, elbow, or hand) lasted for more than one week OR occurred more than three times in the previous 12 months AND no acute traumatic onset (12q=1)
- Symptoms (problems of neck, shoulder, elbow, or hand) presented within seven days prior to the assessment AND no acute traumatic onset (nowq=1)
- Physical exam positive in the same side of body region (pe=1).

Body region specific definition of symptoms

Neck problems: pain, stiffness, spasm, unable to move head, burning, numbness or tingling

Shoulder problems: pain, stiffness, spasm, unable to move arms, burning, numbness or tingling

Elbow problems: pain, aching, stiffness, burning, numbness or tingling

Hand problems: pain, aching, stiffness, burning, numbness or tingling

For CTS, additional symptom criteria apply:

- Symptoms located on palmar hand (variables 'hand1' to 'hand5'); AND
- Symptoms located on thumb, index, middle, ring fingers, digits 1-4, digits 1-5, whole hand, median, or radial (variables 'location1' to 'location5'); AND
- Symptoms of burn, numb/tingle, or pain/numb/tingle (variables 'symptomA1' to 'symptomA5', 'symptomB1' to 'symptomB5').

Definition of physical exams on selected medical conditions

Tension neck syndrome:
Active head rotation (pain in neck/trapezius area) OR
Resisted head rotation (pain in neck/trapezius area) OR
Neck flexion/extension (pain in neck/trapezius area)

Rotator cuff tendinitis:
Resisted shoulder abduction, external rotation, internal rotation (pain in respective tendon insertion area=epaulette area), OR
Active shoulder abduction (pain in rotator cuff region=epaulette area typically at 60-120° ="painful arc")

Lateral epicondylitis:
Resisted wrist extension (pain in lateral epicondyle),
Palpation of lateral epicondyle

Electrodiagnostic Tests

Nerve conduction studies were performed on the dominant hand using standard techniques of supramaximal percutaneous nerve stimulation and surface recording, using Cadwell equipment. Anatomic landmarks and standardized stimulation to recording electrode distances are shown in Table M4. While measuring locations for electrode placement, the wrist is held straight with the fingers extended. Skin temperature was measured using an Electromedics digital skin thermometer. The hand was wrapped in an electric heating pad if necessary to obtain a digital temperature of greater than 32 degrees centigrade. Criteria for median neuropathy at the wrist (consistent with carpal tunnel syndrome) are shown in Table M5. Complete ulnar nerve studies were not done as part of the research protocol. Dr. Gary Franklin, a Board certified neurologist, reviewed all final protocols and methods for the electrodiagnostic testing. He also reviewed all wave form results.

Table M4. Anatomic Landmarks and Distance between Stimulating and Recording Electrodes

Nerve	Recording Electrode	Stimulate	Distance
Median S*	Digit II, proximal & distal phalanxes; 3-4 cm apart	Wrist	14cm
Median S	Wrist, between PL & FCR tendons	Mid palm, mid-thenar crease	8 cm
Median M	Thenar abductor pollicis brevis muscle	Wrist	8 cm
Ulnar S	Digit V, proximal & distal phalanxes; 3-4 cm apart	Wrist	14 cm
Ulnar S	Medial Wrist	Medial palm	8 cm

Abnormal test was based on the Washington Department of Labor and Industries Attending Doctor's Handbook (2005) criteria

Table M5. 'Clinic-Based' Definition of Abnormal Median Nerve Conduction Measures Abnormal if Meet Criteria A and (Criteria B or Criteria C)

Criteria	Description
A	Median motor latency 8cm >4.5 seconds, median sensory latency D2-wrist 14cm>3.5 seconds, or middle palmar latency 8cm>2.2 seconds
B	Ulnar sensory latency 14cm <3.7 seconds
C	Median sensory latency (14cm) minus ulnar sensory latency >1.0 or midpalmar difference >0.05msec

Inter-rater testing was completed for both health and exposure assessments (See Appendix B). With respect to health interviews, there was generally good to excellent agreement with respect to symptoms by area with the lowest agreement for the neck area. For the physical exam, tests were grouped by body area. Kappa values ranged between 0.40 for the left wrist and 0.70 for the right wrist.

We modified the Katz Hand Diagram rating system (Katz, et al, 1990) for use in our epidemiologic study of workers with hand symptoms. Application of the original rating system to a non-screened population of symptomatic workers unlikely to have CTS i.e. with symptoms isolated to finger joints suggesting arthritis, likely would lead to poor estimates of validity of the hand diagram for CTS (See Appendix B).

Additionally, we were interested in comparing our criteria for CTS on the hand diagram (pain/numbness/tingling/burning in the traditional median nerve distribution of the hand) compared to that developed by Katz (1990). Out of 391 hand diagrams on the right side, 40.7% were classified as probable, possible or definite on Katz criteria and 33.2% by our traditional method, 47.9 by either and 26.0% by both (see Appendix B).

Exposure Assessment Methods

Exposure assessment data were collected at the individual subject level by a three-person team of ergonomists blinded to health status. Data were collected at baseline and four month intervals over three years, among workers at 12 different worksites. Work organizational factors were collected at the departmental level by the exposure assessment team. If there was a significant job change, either in workstation geometry or processes, detailed exposure assessment was repeated. Exposure assessment was limited to jobs with four or fewer tasks with minimal mobility (e.g., excluding forklift drivers).

Job Sampling

Job samples were taken from a typical workday where the employee was performing his/her usual type of work at a normal pace without any restrictions by process limitations. This was confirmed at the beginning of the measurement period by discussion with supervisors and workers.

The job sampling approach used in the study was designed according to whether the job was a single task or multiple task job, and whether the tasks were cyclic or non-cyclic (Figure M4). The first step was to determine whether the job is a single task or multiple task job and secondly, to determine if each task is cyclic or non-cyclic. For a cyclic single task job, a continuous 15-minute video sample was taken for the exposure measurement. For non-cyclic single task job, three 5-minute job samples were taken randomly during the workday. This attempted to obtain good equitable exposure measures for this type of job and capture the fluctuations of the exposure during a workday. The total job sample length for a single task job was 15 minutes for both cyclic and non-cyclic task jobs.

For multiple task jobs (more than one task is performed during a workday), a different job sampling method was used for both cyclic and non-cyclic tasks. A ten-minute job sample was taken for each of the cyclic tasks and two 5-minute job samples was randomly taken from each of the non-cyclic tasks in a multiple task job. Depending on the number of tasks, the total length of the job samples was longer in a multiple task job than that in a single task job. Jobs with more than four tasks were excluded for practical purpose, to limit the number of multiple task jobs and the amount of time needed for data collection, processing and analysis.

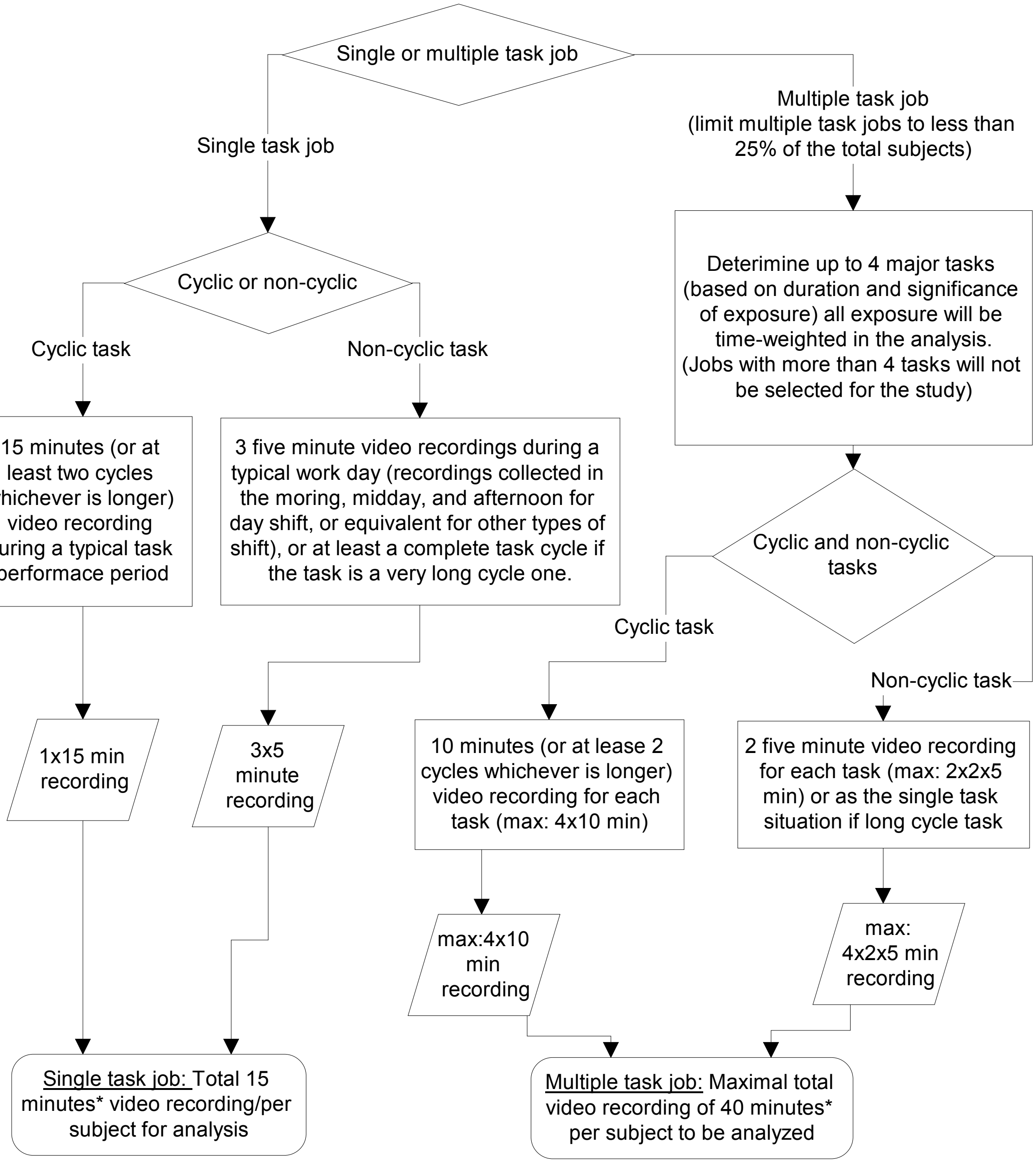

Figure M4. Illustration of the job sampling strategy used for exposure assessment, based on the type of tasks and number jobs.

On-site Data Collection

After the job sampling strategy was determined, jobs were documented and data were collected on site. The on-site data collection form used is shown in Figure 2.

Before taking any exposure measurements, work hours and days, job change information, and task distribution information (task rotation schedule and number of hours at each task) were obtained from interviewing workers and supervisors. Jobs were then video filmed according to the job sampling strategy discussed previously. Two synchronized cameras were used in order to capture both body sides while the worker was performing tasks. Cameras were synchronized by turning on a light at sample initiation and cutting the video samples at this point during video editing. The camera crews were coordinated so that when the worker moved the two camera crews moved accordingly in order to have a good video frame captured by at least once of the cameras.

During the observation period, forces applied in the task were noted and later measured. As it is not feasible to measure all forces that the worker applies in the task, a subjective determination of "significant force" was made. Operationally, when one of the ergonomists considered that the force was obvious and may be of importance to the exposure, the force data was collected. A "significant force" was defined as a pinch grip force of ≥ 0.9 kg, a lifting or power grip force of ≥ 4.4 kg and a push/pull force of ≥ 4.4 kg. The actual force value was not known until measured. Therefore, in practice, forces that were lower than the defined levels were sometimes measured.

Lifting forces were measured by the object weight. This was usually measured by using a digital Chattillon or mechanical Wagner force gauge, or a weight scale on-site. Object weights occasionally were obtained from the company or product specifications. Push/pull force was measured using a force gauge. For practical purposes, no distinction was made between push and pull forces, though they may have different physiological impacts. Both lifting weight and push/pull force were also estimated by an ergonomist using a 1 to 10 rating scale (very, very light to maximal). A pinch or power grip hand force was measured using the force matching method (Bao, 2000). This was done by asking the subject to recreate the amount of force he/she uses in the task on a force dynanometer using similar hand/wrist postures. This process was repeated three times, and the median of the three is used in the analysis. Borg (CR-10) (Borg, 1982) ratings by subjects and researchers were also collected for force applications. This was done in each case by visually showing the subject a scale and asking them to choose a number or verbal anchor. The reason for using different methods for the same exposure parameters was to study the differences and similarities between different measurement methods.

Other observed parameters such as the HAL (Hand Activity Level), and parameters for computing the Strain Index (i.e. duration of exertion, efforts/min, hand/wrist posture, speed of work, and duration per day) were also collected during the on-site data collection period. These measurements were collected for calculation of the event-based exposure estimations. Additionally, if the worker used vibration tools, the tool information was collected for later estimation of exposure from stated tool vibration values. These measurements are represented in the on-site data collection form shown in Figure M5.

Subjects were instructed to perform their jobs normally despite the video observation and care was taken to not affect the task performance during data collection. Measurements were checked at the end of the data collection, to check the completeness of the data and be sure all data were collected properly.

Field Physical Exposure Data Collection Form

Location: ___________________________; Physical location: ____________________

Subject ID: ____________ Analyst(s): ______________ Time: ________________

Period ID:___________________ Initial job category: _______________________

Age: ______; Gender: ❑Male ❑Female; Height: ________ in; Weight: _______ lb

Hand (write): ❑Right ❑Left ❑Both; Hand (work): ❑Right ❑Left ❑Both;

Current job: _____________________ Shift hours: _______ Work days: ________

Task ID	Task Activity	Duration (hrs/d)	Expected time(s)	Cyclic	Note
				Y / N	
				Y / N	
				Y / N	
				Y / N	
				Y / N	

Break times: ____

Power tool information (PT)

Tool ID	Power Tool/Model	Weight	Grip span(s)/Handle Diameter(s)	Note
PT				
PT				
PT				
PT				
PT				

On site direct measurement

Task: ________________________________; Task ID: ______________

Major object handled

Object	Measure (lb)	Estimated[1]	Sub-task description

Significant force measurement

Force type	Measure (lb)	Est[1]	Not measurable?	Sub-task description
❑push ❑pull			❑	
❑push ❑pull			❑	
❑push ❑pull			❑	
❑push ❑pull			❑	

Significant hand force measurement

Measmnt 1 (lb)	Measmnt 2 (lb)	Measmnt 3 (lb)	RPE	Est[1]	Grip type	Not measurable?	Sub-task description
						❑	
						❑	
						❑	
						❑	

Other significant force measurement

Force type *(please describe)*	Measurement (lb)	Est[1]	Not measurable?	Sub-task description
			❑	
			❑	
			❑	
			❑	

Other estimated and observed measurements

	Task average		Note
	Left	Right	
HAL [2]			
Duration of exertion (% of cycle) [3]			
Efforts/min [4]			
Hand/wrist posture [5]			
Speed of work [6]			
Duration per day [7]			

	Check (✓)if yes		Estimated frequency[8]	Sub-task description
	Left	Right		
Power tool use	❑id: ___	❑id: ___		
Contact stress	❑	❑		
Jerking	❑	❑		
Impact action	❑	❑		

1. **Estimated (Est) intensity of force:** 1 (low) to 10 (high)

2. **HAL**

0 – handle idle most of the time, no regular exertions	2 - consistent, conspicuous, long pauses or very slow motions	4 – slow, steady motion/exertions, frequent brief pauses	6 – steady motion/exertion; infrequent pause	8 – rapid, steady motion/exertions; no regular pauses	10 – rapid, steady motions/difficulty keeping up or continuous exertion

3. **Duration of exertion (% of cycle)**

1 - <10%	2 – 10 to 29%	3 – 30 to 49%	4 – 50 to 79%	5 - ≥80

4. **Efforts/min**

1 - <4	2 – 4 to 8	3 – 9 to 14	4 – 15 to 19	5 - ≥20

5. **Hand/wrist posture**

1 – very good	2 – good	3 – fair	4 – bad	5 – very bad

6. **Speed of work**

1 – very slow	2 – slow	3 – fair	4 – fast	5 – very fast

7. **Duration per day**

1 - <1	2 – 1 to 2	3 – 2 to 4	4 – 4 to 8	5 - ≥8

8. **Estimated frequency:** 1 – very infrequent, 2-infrequent, 3-average, 4-frequent, 5-very frequent

Figure M5. The on-site data collection form used for exposure assessment.

Job Analysis ("Significant" or High Force Analysis)

Post-data collection analysis was performed in the laboratory using the video recordings and data collected at the worksite. The video samples were first digitized and edited to contain the appropriate starting point and task content. The purpose of the subsequent analysis was to obtain the frequency and duration of exposure parameters. This was done by performing time studies on the recorded tasks. A software program called MVTA (Multi-Video Task Analysis) developed by The Wisconsin University (Yen and Radwin, 1995) was used for the analysis. A typical data processing screen is shown in Figure M6. The record shows a time-line when a certain event (activities of various "significant" forces) occurred. "Significant" forces are listed in the right panel. The video window shows the recorded task performance. The analyst used video clips from the two synchronized cameras to obtain the best view for the analysis. Time line marks were inserted at the time when significant forces occur. The analysts were instructed to play the video in normal speed first in order to understand the task activity contents and play the video in slow motion mode to set the event marks.

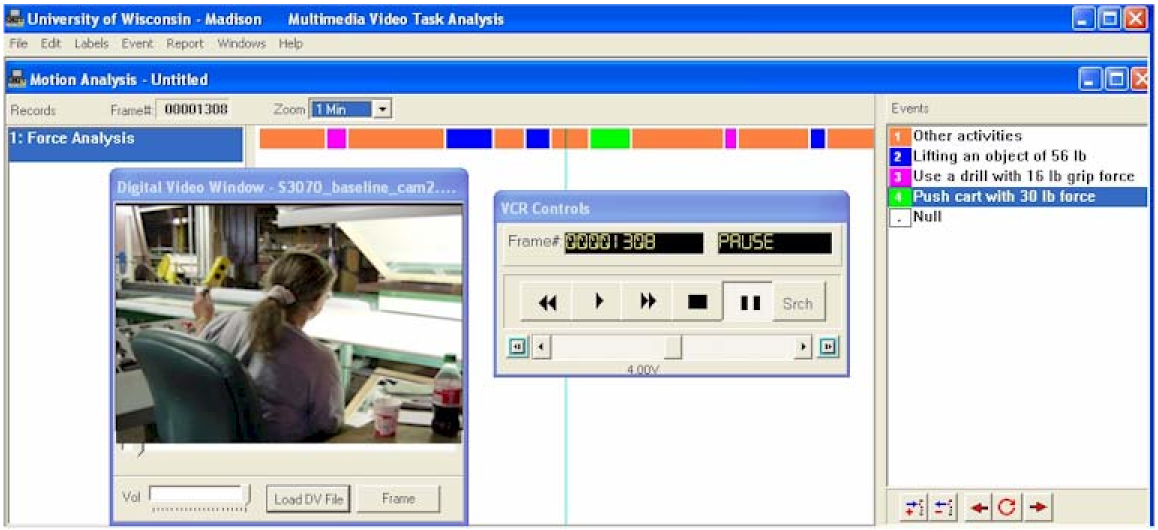

Figure M6. A typical time-study of significant forces using MVTA

Analysis files were first analyzed by the ergonomist (one of three) that had completed the on-site data collection form and worker interview, and thus had the best understanding of the task. The ergonomist cut the video into the measured tasks. The ergonomist then performed the task analysis be marking the MVTA file to designate performance of significant force applications and foreign elements. Frequency, duration and duty cycle of hand exertions and frequency of upper arm movements were calculated using MVTA from analysis performed by laboratory analysts. To reduce between-observer variations of hand exertions and upper arm movements observations, and have the possibility to estimate the between-observer variability, two analysts were assigned to analyze samples from the same task of the same subject.

After the data processing, a time-study report was generated. For an illustrative example, Table M6 shows that at recorded cycle #3, the worker lifted an object of 56 lb for a duration of 142 frames (or 4.7 seconds) and spent 286 frame time (or 9.5 seconds) performing other activities where no significant forces was applied.

Table M6. A typical time-study report of significant forces

Time Study Report

Event#	Event Elements
1	Other activities
2	Lifting an object of 56 lb
3	Use a drill with 16 lb grip force
4	Push cart with 30 lb force

Time Units in Frames

Cycle	Other activities	Lifting an object of 56 lb	Use a drill with 16 lb grip force	Push cart with 30 lb force
1	270			42
2	198		61	
3	286	142		
…	….	….	….	….
66	92	75		
67	110			124
68	272		38	
69	212	49		

Using the time-study report, a summary statistics report was produced where average duration, percent of time and frequency of the significant forces was calculated as follows:

$$\text{Average duration (in sec)} = \frac{\sum \text{duration of individual exertions}}{\text{Total number of exertion cycles}}$$

$$\%\ \text{time} = \frac{\sum \text{duration of individual exertions}}{\text{Total recording time}}\ \text{x}\,100\%$$

$$\text{Frequency of exertion (times/min)} = \frac{\text{Total number of exertions}}{\text{Total recording time}}$$

When the worker used vibration tools during task performance, the vibration exposure was quantified. It was not possible to perform accurate vibration measurements while also collecting a large amount of other physical exposure parameters for each of the subjects. The alternative was to obtain the declared vibration values of the tools that the workers used, and then perform a time-study on the video recordings to measure the actual time that the vibrating tools were activated. This estimation may contain an element of error, as other factors such as tool balancing, work surface conditions and individual work techniques can influence the true vibration level, but it does give a quantifiable estimation of the vibration exposure.

Posture Analysis, Event-based vs. Time-based

Posture analysis was performed using the video and MVTA files of recorded tasks. There were two types of posture analyses, “event-based” and “time-based”. For “event-based” posture analysis the overall postures (the most common posture and the worst posture) for the different body parts when performing a specific task were determined. In “time-based” posture analysis, postures were measured at a particular time for a specific task. There were two types of analyses for the time-based posture analysis: 1) continuous observation, and 2) time-sampled observation.

In the continuous observation, the analyst observed the postures of the different body parts continuously, and marked the changes whenever the body part moved from one pre-defined angular category to another. This analysis allowed determination of the distribution of the angles of the different body parts and the movement frequency between the different pre-defined angular categories. However, this type of analysis is very time-consuming, particularly when there are several pre-defined angular categories for that body part. Also, it is very difficult to observe several body parts simultaneously. Therefore, the analyst must play the video several times in order to complete the analyses for the different body parts.

In the time-sampled observation of the time-based posture analysis, the analyst observed the postures at a number of pre-selected times during the task performance, and a distribution of the postures was calculated. Although this method significantly reduces the data processing time, it is not possible to obtain information about repetitive movements of the different body parts in combination with the postures from this portion of the analysis. Both event-based and time-based posture analyses were performed for each of the subjects.

The event-based postural analysis was completed during video editing by the ergonomist that completed the on-site data collection. In the event-based posture analysis, pre-defined postures were used (Table M7). Posture distribution results were then be calculated and used for epidemiological modeling. An illustrative distribution result is shown in Figure 5, where job A seems to have more wrist extensions and flexion compared to job B and workers at job B maintain more neutral wrist postures compared to workers at job A. Depending on the need of the epidemiological analysis, some of the pre-defined angular categories may be consolidated. Using the event-based posture results, one can also calculate certain indices for the different body parts, such as the RULA scores. To obtain the final RULA score, apart from the posture results, additional information such as forces and muscle use should also be obtained. Details on the computation of RULA scores can be found in relevant articles (McAtamney and Corlett, 1993).

In the time-based posture analysis, postures of the same body regions used in the event-based posture analysis were measured. However, instead of giving overall estimated posture values for an entire task (event), postures were observed at certain points of time during a task performance. In the SHARP Study, postures were estimated for numerous randomly selected frames during a 15-minute task recording (75 frames for a single task job, 80 frames for a 2 task job, 90 frames for a 3 task job and 100 frames for a 4 task job). To lower individual analyst variation, the frames are assigned to two analysts for processing.

Table M7. Pre-defined angular categories for the different body parts

Trunk	Trunk flexion-extension < 0° (extension) 0° to 20° (flexion) 20° to 60° > 60°	Trunk lateral flexion 0° to 10° 10° to 30° > 30°	Trunk twisting 0° to 10° 10° to 45° > 45°
Neck	Neck flexion-extension < 0° (extension) 0° to 20° (flexion) > 20°	Neck lateral flexion 0° to 10° 10° to 30° > 30°	Neck twisting 0° to 10° 10° to 45° > 45°
Upper arms	Upper arm flexion-extension < 0° (extension) 0° to 20° (flexion) 20° to 45° 45° to 90° > 90°	Upper arm abduction-adduction < 0° (adduction) 0° to 30° (abduction) 30° to 60° 60° to 90° > 90°	Upper arm rotation < 0° (outward) 0° to 15° (inward) 15° to 45° > 45°
Shoulders and elbows	*Shoulder raise* Yes or no	Arm supported Yes or no	Elbow flexion < 0° (extension) 0° to 20° (flexion) 20° to 60° 60° to 100° > 100°
Forearms and wrists	Forearm rotation -180° to -90° (supination) -90° to 0° (supination) 0° to 90° (pronation) 90° to 180° (pronation)	*Wrist flexion-extension* < -45° (extension) -45° to -15° -15° to 0° 0° to 15° (flexion) 15° to 45° > 45°	*Wrist ulnar-radial deviation* < -15° (radial) -15° to -5° -5° to 0° 0° to 10° (ulnar) 10° to 20° > 20°

One of the potential problems with pre-defined angular categories is that the analyst may be biased by the nature of the job. For instance, when a posture is on the threshold of two pre-defined angular categories (e.g. posture is approximately 30° while the categories are 0° to 30° and 30° to 60°), the analyst may assign the worse posture category to the subject when he/she thinks the job is hazardous, or vice versa. To overcome this problem, a continuous angular scale was used during data processing (posture estimate) and then the data was categorized later during the analysis. In order to make the continuous scale for the posture estimate, a special data processing program was created (COMPASS). One of the data processing screens from COMPASS is shown in Figure M7. In this screen the worker is shown from two camera angles (pictures are just for illustrative purpose in the figure and does not represent the actual analysis) at a pre-selected video frame. The analyst observed the posture and estimated the approximate locations of the body parts by clicking on the posture diagrams. The continuous angle data were automatically entered into a database.

From the raw posture data, posture distributions were computed based on pre-defined angle categories (e.g. Job A: 15% time wrist extension > 45°, 67% wrist extension 45° to flexion 15°, and 18% time in flexion > 15°; Job B: 8% time in wrist extension > 45°, 82% time in wrist extension 45° to flexion 15°, and 10% time in flexion > 15°). This analysis also allowed for descriptive statistics for individual subjects such as mean, median, 95%ile etc. of the postures can to be calculated.

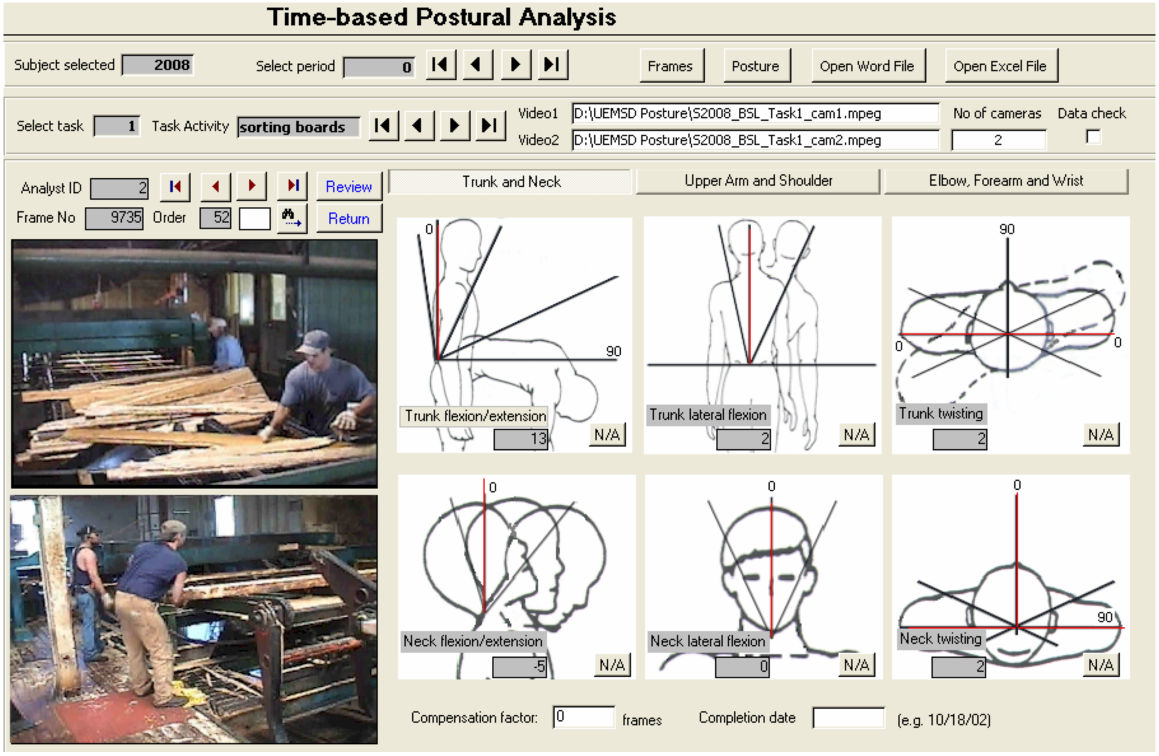

Figure M7. Time-based posture analysis using continuous angular scales (data does not represent the actual angle measurements) in COMPASS program developed by SHARP.

Repetitive Exertion Analysis

Hand exertion was defined as any physical effort of the hand when performing a task activity. This was different from the significant force applications, which may not include all hand exertions. This MVTA analysis was another way to capture exposure during hand activity. The purpose of this analysis is to calculate the frequency of exertion (or cycle time of exertion), duration of exertion, and exertion duty cycles (% exertion). In this analysis, completed in the laboratory, each hand was analyzed separately. To reduce processing time, particularly when the tasks were of a very repetitive nature, the analysis was on 5 randomly selected one-minute intervals of the recorded task instead of the whole video recording.

A typical repetitive exertion MVTA analysis window is shown in Figure M8. From this analysis, a raw data report, containing durations of individual exertion and non-exertion events, were generated. The raw data report can be used to calculate the following:

$$\text{Average duration of exertion (in sec)} = \frac{\sum \text{duration of individual exertion}}{\text{Number of exertion cycles}}$$

$$\text{Average cycle time (in sec)} = \frac{\text{Total recording time}}{\text{Number of exertion cycles}}$$ or

$$\text{Average frequency of exertion (times/min)} = \frac{\text{Number of exertion cycles}}{\text{Total recording time}}$$

$$\text{Average duty cycle (\%)} = \frac{\sum[\text{Individual exertion} / (\text{Individual exertion} + \text{individual non - exertion})]}{\text{Number of exertion cycles}} \times 100\%$$

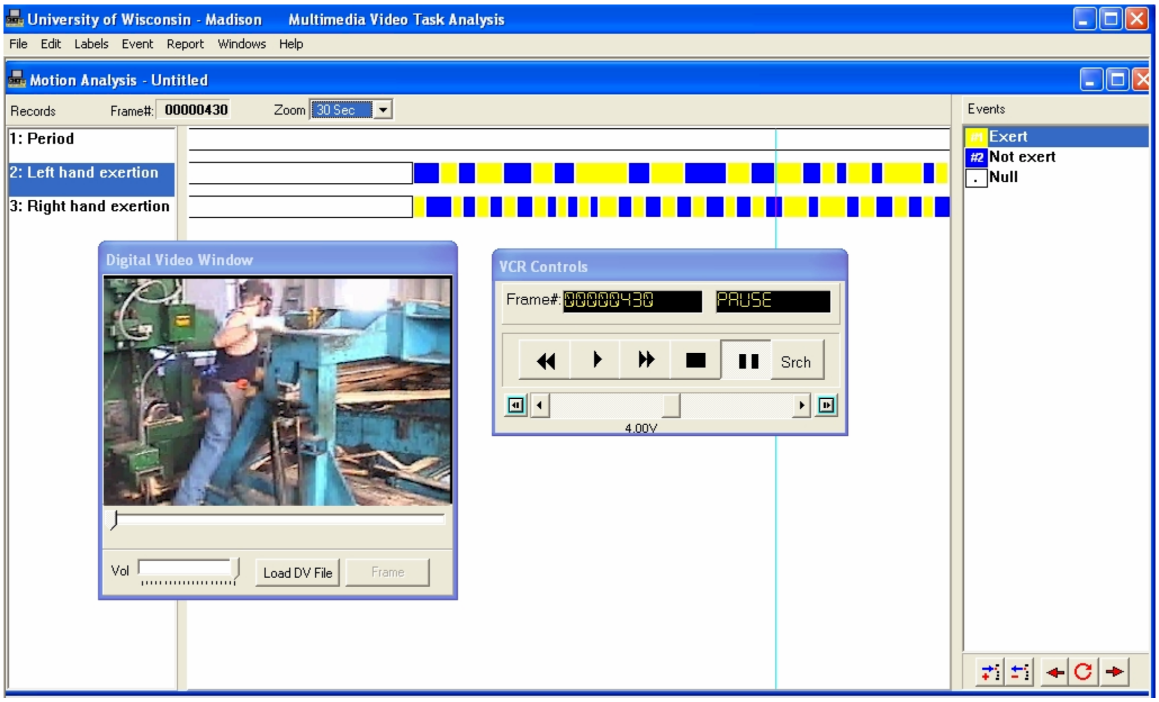

Figure M8. A typical repetitive exertion analysis screen in MVTA.

Repetitive Movement Analysis

Repetitive movement analysis quantified the frequency of movements for a specific joint. Shoulder movements were quantified through a time study of the recorded tasks using the MVTA program. Two events were defined to distinguish the directions of the shoulder (the upper arm) movements. A complete movement cycle was defined as movement of the upper arm from one direction to another. Again, the left and right shoulders are analyzed separately. Average frequency of the shoulder movement was then computed based on the raw data report generated by the MVTA program.

$$\text{Average frequency (times/min)} = \frac{\text{Number of movement cycles}}{\text{Total recording time}}$$

Work Organization Measurement

This study was associated with the NIOSH Research Consortium on Work-related Musculoskeletal Disorders, along with other US research groups. One of the first collaborative efforts of the consortium was to develop an observational assessment tool for work organization characteristics adapting elements from AET (Rohmert & Landau, 1983), EWA (Ahonen and Launis, et al. 1996) and VERA (Volpert, Kötter, et al. 1989). The intent of the checklist is to characterize several aspects of the organization of work. These aspects are:

A) The physical aspects of the work (temperature, humidity, illumination, noise, general housekeeping)
B) Job content at the task level (repetitiveness, pacing, pacing control, job rotation, labor type, postural demands)
C) The social aspects of the work (group coordination, gender segregation)
D) Global job content (attentiveness demands, use of skills, mental demands, structural restraints of task activities)
E) Temporal aspects of the work (work hours, break schedule, shift work)

This 2-page checklist (Appendix A) was completed at the department level for all job sites during baseline exposure by one of three ergonomists. Department evaluations were randomly assigned. Prior to specific job physical demand parameter observations, supervisors and workers were queried about number and type of tasks and their usual duration, rotation patterns, and upset conditions. An ergonomist observed the department that the worker was in for environmental factors, demographic segregation, work method, social content, pacing, positioning, preparation for action, flexibility, attentiveness demands (adapted from EWA, 1996), responsibility for the safety of others, and job content. Although ambient environment tended to be the same for all study jobs in a department, if there were substantial differences between jobs in some of the areas of interest, these were collected at the job or sub-department level. During subsequent visits, changes to the work organization were documented using the checklist.

Inter-rater testing was completed for both health and exposure assessments (See Appendix B). With respect to health interviews, there was generally good to excellent agreement with respect to symptoms by area with the lowest agreement for the neck area. For the physical exam, tests were grouped by body area. Kappa values ranged between 0.40 for the left wrist and 0.70 for the right wrist.

E. STATISTICAL METHODS

Our primary interest has been in identifying individual factors (demographic, general health and social demands), psychosocial factors (demands, decision latitude, SF-12), work organizational and then physical workload factors, that may be associated with prevalent or incident clinical cases of tension neck syndrome, rotator cuff tendinitis, lateral epicondylitis and carpal tunnel syndrome. The analysis included an exploratory phase, followed by a more definitive analysis to test hypotheses about physical workload and UEMSD.

Exploratory Analysis

Initial descriptive analyses and exploratory analysis were conducted with histograms, scatter-plots, box-plots, frequency tables, and descriptive statistics. We evaluated all of the variables collected for this study including the demographics, psychosocial factors, SF-12, work organization, and physical exposure factors. The quantitative descriptions were summarized for the complete study population (N=733) at baseline, and at each of the three annual visits.

Further exploratory data analysis aimed to identify and describe patterns and trends of the data were conducted for the entire study population and by the major diagnoses of the upper extremity SD including tension neck syndrome, rotator cuff tendinitis, lateral epicondylitis, and carpal tunnel syndrome. Because the general aim was to assess the effects of physical exposure imposed on the upper extremities in work activities, we focused on determining the optimal cut points for each of the exposure variables. Where possible, cut points for the exposure variables were based on the previous, although limited, epidemiological literature (Bernard 1997, NAS 2001, Fallentin 2001, Ariens 2001, Punnett, Gold et al 2004, Punnett & Van der Beek 2000, Roquelaure 2006), the biomechanical and physiological studies (Viikari-Juntura and Silverstein, 1999), and the distributions of the data in our study population. Where there were inadequate numbers in trichotomous exposure cells, we combined categories into dichotomous cells.

Hypothesis Testing and Model-building

We have conducted logistic regression and survival analyses to test the hypothesis that the frequency, duration or intensity (amplitude) of exposure to high forces and or awkward postures plays a role in the development of UEMSD in a working population.

For the clinical cases at baseline, we used logistic regression relating the presence of a diagnosis of an upper extremity MSD with any of the personal, psychosocial or physical exposure variables. The logistic regression was initially carried out for one dependent and one independent variable at a time. We made the decision to include age, gender and BMI in all models. Those independent variables that have striking or statistically significant associations with the outcome variables were evaluated together using multivariate logistic regressions. All of the multivariate analyses were adjusted for age, gender and BMI in these data. The final multivariate logistic regression models were obtained after exploring the separate models for the demographic variables, psychosocial factors, SF-12, work organization factors. Any of the independent variables that were still statistically significant in these separate models were considered in the final model, adjusted for age, gender and BMI. The interactions between individual factors and exposure variables, as well as between different exposure variables were also explored. The final multivariate logistic regression model assessed the association between the diagnosis of a specific upper extremity MSD and the physical work factors of force and posture (characterized by intensity, frequency, duration) at the same time, while adjusting for other important individual factors. These final models provided information on whether there was a differential impact of force or posture on the presence of the clinical cases of a specific upper extremity MSD.

For the incident cases of UEMSD that were identified during the follow-up visits, we used survival analyses to explore the association between physical exposures and the development of the adverse health outcome. These analyses were restricted to the participants who did not change physical exposures (i.e., no job changes) during the study. We conducted time-to-event analyses using Kaplan-Meier plots and the log rank test to test one predictor variable at a time. We used the Cox proportional hazards model for multivariate analysis. Similar model building strategies for the baseline data applied for the multivariate analysis on the time-to-event data using the survival analyses. The final multivariate Cox proportional hazards model assessed the frequency, intensity and duration of force and posture at the same time while adjusting for other important individual factors. These final models enabled us to determine if there was a differential impact of force and posture (in terms of the frequency, intensity or duration) in development of the new cases of specific upper extremity MSDs in the study population.

Statistical software for analyses included SAS (v 9.1), Stata (Intercooled v8) or SPSS for Windows (v14.0). Survival analysis with was used to evaluate models in which there were no job changes for subjects over the course of their participation.

F. WMSD CONSORTIUM METHODS

NIOSH initiated a research initiative on WMSDs in a series of cooperative agreements to conduct prospective studies of back and upper extremity WMSDs. In addition to NIOSH, upper extremity studies are being conducted by:

- Washington State's SHARP program, B Silverstein, PI;
- Universities of Wisconsin-Milwaukee/Utah, A Garg, PI;
- University of California-San Francisco, D Rempel, PI;
- University of Iowa, F. Gerr, PI;
- University of Connecticut, M Cherniak, PI (primarily doing hand/arm vibration studies with overlap in upper extremity).
- Washington University, St. Louis, B Evanoff, PI

In addition there are four other projects that are being conducted as part of the consortium work:

- NIOSH, low back study, S. Burt, PI;
- Ohio State University, W. Marras, PI;
- University of Wisconsin-Milwaukee/Utah/Texas, A. Garg, PI.
- NIOSH Hand/Arm Vibration team methods development, R. Schopper, PI

In March of 2004, the SHARP Program agreed to undertake a phase 1 feasibility study to systematically evaluate the upper extremity data collection methods, variables and protocols of the different studies to determine if data sharing between some or all consortium members would be possible.

While all of the study designs are different, there is great value in evaluating whether some or all studies or parts of studies could be combined to increase statistical power above what any individual study could achieve. It also increases the possibility of comparing health effects and exposure assessment methods to determine more useful metrics for researchers and practitioners alike. Very few musculoskeletal studies have had individual exposure assessments and clinical health outcomes conducted prospectively. These studies represent some of the richest data sources in the world for better understanding the natural course of musculoskeletal disorders in working populations, relevant clinical and exposure methods to use, as well as the opportunity to develop more focused prevention strategies.
Data collection methods, variables and protocols from four upper extremity (UE) members of the WMSD Consortium were reviewed from February to April, 2004. Initial findings were discussed at the consortium meeting in Columbus Ohio in April of 2004. Three new consortium members were present at this meeting, and discussions were held on the ability of new studies to incorporate some of the same health and exposure data elements used by the existing members, to increase data sharing capabilities. Work continued on the phase 1 feasibility study as new and existing members modified study instruments and forwarded them to the SHARP research staff. A review of all seven UE studies preliminary findings was conducted at the consortium meeting in Washington D.C., in December 2004. Receipt of final instruments occurred in February of 2005.

SHARP research staff systematically reviewed study designs, protocols and data collection instruments. All health data was subsequently reduced to individual variables and reviewed for comparability. Physical examination protocols and recordings of physical examinations being conducted were sent to SHARP to determine whether tests with the same name were conducted in an equivalent manner. Differences were noted. Electrodiagnostic test protocols and instrumentation documentation were also sent to SHARP for comparability evaluation.

Additional information was collected at Consortium meetings such as placement of the temperature collection devise and methods for warming the hands. Questionnaire/Interview questions (and possible answers) were categorized into individual demographics, health history and social factors, work history factors and symptoms descriptions. Psychosocial questions were also compared for concurrence with existing scales (e.g., Karasek) or similar dimensions. Exposure assessment protocols and descriptions were obtained during a site visit or from telephone interviews with those involved in exposure assessment. After considerable amounts of data had been collected, SHARP compiled spreadsheets for each area (physical examination, interview, exposure assessment, etc.) and sent the spreadsheets to study coordinators for review. This was an iterative process because a number of projects were in the process of finalizing their instruments and protocols during this period. Discussion of discrepancies and commonalities took place during consortium meetings or via telephone conference calls.

All health data variables were collected from 7 consortium members between February, 2004 and February 2005. Variables were reviewed by three SHARP researchers for direct comparability. Final review of health variables was completed in March, 2005 by SHARP research staff.

G. RESULTS

Participation

For the baseline visit, we completed both health and exposure assessments for 733 fulltime workers in the 12 study sites. Subsequently, we lost varying numbers of subjects from each site with subsequent interim and annual follow-up visits (Tables R1 and R2). Site 3 had the most significant losses due to decreasing product demands and resorting to temporary workers which were then not eligible for study. Given the volatility in the economy during the study period, it was fortuitous that we conducted interim assessments. Of the 733 who completed baseline assessments, 467 completed annual 1 assessment, but 567 had completed the first follow-up. There were 377 subjects that completed annual 1 and annual 2 visits and 266 that also completed annual 3 visits. Continuing loss to follow-up ranged between 6-12% with each subsequent visit.

Table R1. Loss to follow-up by site

		Cumulative lost to study by year			
Site	**Total enrolled by site**	**Baseline**	**Year 1**	**Year 2**	**Year 3**
Site 1	37	0	2	7	10
Site 2	58	0	23	24	30
Site 3	95	0	46	74	76
Site 4	71	0	15	21	28
Site 5	114	0	25	40	55
Site 6	58	0	12	29	34
Site 7	72	0	21	27	30
Site 8	63	0	12	17	23
Site 9	53	0	14	22	22
Site 10	39	0	4	8	9
Site 11	50	0	17	21	
Site 12	23	0	5	8	8
Cumulative # lost to study	733	0	196	298	325

		Cumulative percent of subjects lost to follow-up		
Site	**Total enrolled by site**	**Year 1**	**Year 2**	**Year 3**
Site 1	37	5.4%	18.9%	27.0%
Site 2	58	39.7%	41.4%	51.7%
Site 3	95	48.4%	77.9%	80.0%
Site 4	71	21.1%	29.6%	39.4%
Site 5	114	21.9%	35.1%	48.2%
Site 6	58	20.7%	50.0%	58.6%
Site 7	72	29.2%	37.5%	41.7%
Site 8	63	19.0%	27.0%	36.5%
Site 9	53	26.4%	41.5%	41.5%
Site 10	39	10.3%	20.5%	23.1%
Site 11	50	34.0%	42.0%	
Site 12	23	21.7%	34.8%	34.8%

Table R2. Subject status at each visit

	Base line	Follow-up 1	Follow-up 2	Follow-up 3 (1 site)	Year 1	Follow-up 4	Follow-up 5	Year 2	Follow-up 6	Follow-up 7	Year 3
# subjects seen each visit	733	567	410	51	467	375	311	377	264	209	266
# subjects missed each visit	0	101	220	12	69	79	64	56	61	58	23
# subjects lost to study each visit	0	65	38	4	86	34	32	22	38	20	18

Population Distributions

Population Demographics

The study population demographics over the course of the study are described in Table R3. The population decreased in numbers but increased in age, BMI and years on the job. A higher percent of subjects at baseline rated their physical health as low (49.8%) compared to those who were still participating three years later (39.5%). This raises the possibility of a survivor bias or healthy worker effect.

Table R3. Summary of demographics and SF-12 of the study population by visit year

Characteristics	**Baseline (n=733)**	**Year one (n=467)**	**Year two (n=375)**	**Year three (n=266)**
Age, mean ± SD	39.5 ± 11.0	41.3 ± 10.9	43.1 ± 10.3	44.5 ± 10.0
BMI, mean ± SD	27.3 ± 5.8	27.4 ± 5.6	28.1 ± 5.5	28.1 ± 5.4
Years in current job, median (Q1-Q3)	2.4 (0.7-5.4)	3.5 (1.6-6.7)	4.3 (1.9-7.4)	5.3 (2.5-9.8)
Gender (% male)	52.3	48.8	46.7	49.6
Race (% white)	59.5	58.5	58.1	57.5
% with medical disorders*	19.5	21.2	23.6	23.3
SF-12**	n=627	n=386	n=323	n=223
Low PCS 12	49.8	46.9	46.7	39.5
Low MCS 12	50.6	48.4	54.5	50.2

*Medical disorders include diabetes, high blood pressure, gout or thyroid.

Table R4 indicates a much larger proportion of subjects who were symptomatic but without physical findings at the time of the examination compared to those who were clinical cases (Table R5). It is of note that the proportion reporting current back symptoms was much lower than for upper extremity symptoms.

Table R4. Number of subjects meeting current symptoms definition *

	Visits**			
Current symptoms cases	**Baseline**	**Annual one**	**Annual two**	**Annual three**
Neck symptoms	152	71	57	47
Dominant side shoulder symptoms	140	70	64	29
Non-Dominant side shoulder symptoms	85	58	56	23
Dominant side elbow/forearm symptoms	101	62	51	33
Non-Dominant side elbow/forearm symptoms	70	47	34	23
Dominant side hand/wrist symptoms	233	136	109	58
Non-Dominant side hand/wrist symptoms	157	99	74	43
Back symptoms	78	x	x	x

**N=733 at baseline; n=467 at annual one; n=377 at annual two; and n=266 at annual three.

*current symptoms: recurring symptoms >3 times or lasting more than one week AND present during the last week AND no acute traumatic onset.

Table R5. Number of clinical cases by visits*

	Visits**			
Clinical cases	**Baseline**	**Annual one**	**Annual two**	**Annual three**
Tension neck	38	41	28	25
Dominant side rotator cuff tendinitis	55	38	26	19
Non-dominant side rotator cuff tendinitis	36	23	20	15
Dominant side lateral epicondylitis	38	38	22	18
Non-dominant side lateral epicondylitis	23	28	16	17
Dominant side medial epicondylitis	17	15	14	9
Non-dominant side medial epicondylitis	12	9	9	7
Dominant side carpal tunnel syndrome	63	46	37	23
Non-dominant side carpal tunnel syndrome	40	30	26	14

*N=733 at baseline; n=467 at annual one; n=377 at annual two; and n=266 at annual three.
**Considered clinical cases at follow-up visits between each annual visit.

Work Organization

Work organizational parameters and their distribution in the population at baseline are presented in Table R6.

Table R6. Work Organization Variables and Definitions

Variable Description	Categories	Population Distribution, n=733 (%)
VIGILANCE:		
Attentiveness demands	1=superficial	106 (14.6%)
	2=average	256 (35.3%)
	3=somewhat high	248 (34.2%)
	4=very high	115 (15.9%)
DEMOGRAPHICS:		
Other demographic segregation	0=no	724 (99.9%)
	1=yes	1 (0.1%)
Overall job gender mix	1=male	176 (24.7%)
	2=female	127 (17.8%)
	3=mixed	409 (57.4%)
Sub-task gender segregation	0=no	648 (89.4%)
	1=yes	77 (10.6%)
ENVIRONMENTAL:		
Housekeeping	1=very good	170 (23.4%)
	2=good	294 (40.5%)
	3=bad	218 (30.1%)
	4=very bad	43 (5.9%)
Task illumination	1=adequate	691 (96.1%)
	2=too bright	28 (3.9%)
	3=too low	0
Noise level	1=normal talk	301 (41.5%)
	2=yell	224 (30.9%)
	3=hearing protection	200 (27.6%)
TASK LEVEL:		
Job position type	1=temporary	273 (37.6%)
	2=full-time, hourly	226 (31.2%)
	3=full-time, salaried	226 (31.2%)
Labor content: type of production work	1=direct production	526 (79.0%)
	2=indirect production	139 (21.0%)
Labor content: skill level of workers	1=non-skilled	172 (24.1%)
	2=semi-skilled	103 (14.4%)
	3=skilled manual	296 (41.4%)
	4=skilled trade	40 (5.6%)
	5=professional	104 (14.5%)

	Variable Description	Categories	Population Distribution, n=733 (%)
	Pacing control of work	1=none	165 (22.8%)
		2=manual over-ride	42 (5.8%)
		3=event triggered	162 (22.3%)
		4=work ahead	30 (4.1%)
		5=inventory “buffer”	198 (27.3%)
		6=material staging	99 (13.7%)
		7=regular informal breaks	29 (4.0%)
	Pacing determinant of work	1=self	143 (19.7%)
		2=social/peer	117 (16.1%)
		3=machine	217 (29.9%)
		4=line	173 (23.9%)
		5=piece rate	5 (0.7%)
		6=quota	70 (9.7%)
	Positioning: job activities	1=single task, single activity	273 (37.6%)
		2=multiple tasks	226 (31.2%)
		3=single task, multiple activities	226 (31.2%)
	Body movement in job	1=dynamic	385 (53.9%)
		2=static	206 (28.8%)
		3=both	124 (17.3%)
	Preparation for action	1=none	330 (45.5%)
		2=maintain ‘working posture”	94 (13.0%)
		3=part handling	261 (36.0%
		4=maintain grasp of tool/other	40 (5.5%)
	Job rotation	0=no	503 (69.4%)
		1=yes	222 (30.6%)
	Social content of job	1=individual	312 (43.0%)
		2=work team, min coordination	86 (11.9%)
		3=work team, mod coordination	188 (25.9%)
		4=work team, high coordination	139 (19.2%)
	Work method	1=assembly line	378 (52.2%)
		2=work cells	214 (33.3%)
		3= desk work	105 (14.5%)
WORK GROUP:			
	Flexible work arrangements	0=no	633 (87.3%)
		1=yes	42 (5.8%)
		2=somewhat	50 (6.9%)
	Flexible break possibilities	0=no	333 (45.7%)
		1=yes	150 (20.7%)
		2=somewhat	244 (33.7%)
	Flexible work hours	0=no	675 (93.1%)
		1=yes	22 (3.0%)
		2=somewhat	28 (3.9%)

	Variable Description	Categories	Population Distribution, n=733 (%)
	Formal break schedule	0=no	70 (9.7%)
		1=yes	617 (85.1%)
		2=somewhat	38 (5.2%)
	Shift work	0=no	644 (88.8%)
		1=yes	50 (6.9%)
		2=somewhat	31 (4.35)
	Extended work hours	1=8 hours	460 (63.4%)
		2=10 hours	234 (32.3%)
		3=12 hours	18 (2.5%)
		0=Other	13 (1.8%)
STRUCTURAL CONSTRAINTS:			
	Job constraints	1=very minor structural constraints	1 (0.1%)
		2=little structural constraints	37 (5.1%)
		3=average structural constraints	89 (12.3%)
		4=strong structural constraints	205 (28.3%)
		5=very strong structural constraints	393 (54.2%)
SAFETY:			
	Responsibility for safety of others	1=does not apply	101 (13.9%)
		2=very limited	224 (30.9%)
		3=limited	265 (36.5%)
		4=average	103 (14.2%)
		5=significant	13 (1.8%)
		6=very significant	19 (2.6%)

Inter- and intra-reliability between work organizational variables was evaluated using weighted kappa coefficients. For intra-reliability, individual analysts' responses were paired across different time period. For inter-rater reliability, analysts' evaluations of each variable were paired by department.

Results showed slight to substantial agreement (Landis and Koch, 1977) among variables for intra-rater reliability, with most variables showing significant agreement. Reliability ranged between fair and near perfect for inter-rater reliability. All but three variables (preparation for action, attentiveness demands and flexible break schedule) were shown to be statically significant. Three variables did not have sufficient data to analyze: flexible work arrangements, shift work and lighting.

Job Exposure

For the physical load exposure parameters used in this study, we used different cut-points for some of the same variables depending on the part of the upper extremity with which we were concerned. For those variables where a cell had less than 10% of the population, the cell was combined with the next cell. Tables R6 and R7 present the cut-points and their distributions for force and posture related variables. Most exposure parameters were assessed in several different ways. For example, power grip was described as a) measured through a force matching procedure, b) estimated by the ergonomist or c) estimated by the subject (RPE). The power grip is then described in terms of it’s a) peak level, b) most common level, c) percent of time, and d) frequency. “Forceful exertion” is defined as more than 2 lbs pinch grip or as more than 10 lbs power grip, lifting or push-pull. Time-weighted averages are indicated in the tables.

Table R7. Description and Distribution of Force Variables

	Variable Description (unit of measurement)	Level	Category Cut-point	Population Distribution (n=733)
TEMPORAL:				
	Frequency of forceful exertions (times/min)	1	≥ 5	26.19
		2	0.6 ≤ x <5	41.20
		3	< 0.6	32.61
	Duty cycle of forceful exertions (% time)	1	≥ 17	34.11
		2	3 ≤ X <17	33.56
		3	< 3	32.33
POWER GRIP:				
	Power grip force, time-weighted average (% time)	1	≥ 15	9.41
		2	0.01 ≤ X <15	18.01
		3	< 0.01	72.58
	Power grip force, time-weighted average (times/min)	1	≥ 1.4	13.78
		2	0.01 ≤ X <1.4	13.64
		3	< 0.01	72.58
	Measured power grip force, time-weighted average (lbs)	1	≥ 29	10.10
		2	0.01 ≤ X <29	17.33
		3	< 0.01	72.58
	Worker self-reported power grip force, time-weighted average (rating score of 0 to 10)	1	≥ 3	16.42
		2	0.01 ≤ X <3	10.81
		3	< 0.01	72.78
	Ergonomist estimated power grip force, time-weighted average (rating score of 0 to 10)	1	≥ 3	14.32
		2	0.01 ≤ X <3	13.10
		3	< 0.01	72.58
	Measured peak power grip force (% time)	1	≥ 10	9.82
		2	0.01 ≤ X <10	17.60
		3	< 0.01	72.58
	Frequency of measured peak power grip force (times/min)	1	≥ 1.2	13.23
		2	0.01 ≤ X <1.2	14.19
		3	< 0.01	72.58
	Measured peak power grip force (lbs)	1	≥ 29	13.78
		2	0.01 ≤ X <29	13.64
		3	< 0.01	72.58
	Estimated peak power grip force (% time)	1	≥ 14	7.91
		2	0.01 ≤ X <14	19.51
		3	< 0.01	72.58
	Frequency of estimated peak power grip force (times/min)	1	≥ 1.2	13.10
		2	0.01 ≤ X <1.2	14.32
		3	< 0.01	72.58
	Estimated peak power grip force (lbs)	1	≥ 3.5	12.69
		2	0.01 ≤ X <3.5	14.73
		3	< 0.01	72.58
	Estimated common power grip force (% time)	1	≥ 12	10.23
		2	0.01 ≤ X <12	17.19
		3	< 0.01	72.58
	Frequency of estimated common power grip force (times/min)	1	≥ 1.2	14.05
		2	0.01 ≤ X <1.2	13.37
		3	< 0.01	72.58
	Estimated common power grip force (lbs)	1	≥ 3	18.83
		2	0.01 ≤ X <3	8.59
		3	< 0.01	72.58

	Variable Description (unit of measurement)	Level	Category Cut-point	Population Distribution (n=733)
PINCH GRIP:				
	Pinch grip force, time-weighted average (% time)	1	≥ 10	17.87
		2	0.01 ≤ X <10	18.42
		3	< 0.01	63.71
	Frequency of pinch grip force, time-weighted average (times/min)	1	≥ 3	18.28
		2	0.01 ≤ X <3	18.01
		3	< 0.01	63.71
	Measured pinch grip force, time-weighted average (lbs)	1	≥ 11	18.14
		2	0.01 ≤ X <11	18.14
		3	< 0.01	63.71
	Worker self-reported pinch grip force, time-weighted average (rating score of 0 to 10)	1	≥ 3	20.49
		2	0.01 ≤ X <3	15.71
		3	< 0.01	63.80
	Ergonomist estimated pinch grip force, time-weighted average (rating score of 0 to 10)	1	≥ 3	20.19
		2	0.01 ≤ X <3	16.10
		3	< 0.01	63.71
	Measured peak pinch grip force (% time)	1	≥ 7	18.28
		2	0.01 ≤ X <7	18.01
		3	< 0.01	63.71
	Frequency of measured peak pinch grip force (times/min)	1	≥ 2.2	18.28
		2	0.01 ≤ X <2.2	18.01
		3	< 0.01	63.71
	Measured peak pinch grip force (lbs)	1	≥ 13	19.78
		2	0.01 ≤ X <13	16.51
		3	< 0.01	63.71
	Estimated peak pinch grip force (% time)	1	≥ 8	17.46
		2	0.01 ≤ X <8	18.83
		3	< 0.01	63.71
	Frequency of estimated peak pinch grip force (times/min)	1	≥ 2.4	18.01
		2	0.01 ≤ X <2.4	18.28
		3	< 0.01	63.71
	Estimated peak pinch grip force (lbs)	1	≥ 4	19.78
		2	0.01 ≤ X <4	16.51
		3	< 0.01	63.71
	Estimated common pinch grip force (% time)	1	≥ 9	17.33
		2	0.01 ≤ X <9	18.96
		3	< 0.01	63.71
	Frequency of estimated common pinch grip force (times/min)	1	≥ 2.7	18.01
		2	0.01 ≤ X <2.7	18.28
		3	< 0.01	63.71
	Estimated common pinch grip force (lbs)	1	≥ 3	25.65
		2	0.01 ≤ X <3	10.64
		3	< 0.01	63.71
MANUAL HANDLING:				
	Lifting force, time-weighted average (% time)	1	≥ 20	15.55
		2	0.01 ≤ X <20	46.11
		3	< 0.01	38.34
	Frequency of Lifting force, time-weighted average (times/min)	1	≥ 5	14.73
		2	0.01 ≤ X <5	46.93
		3	< 0.01	38.34
	Measured lifting force, time-weighted average (lbs)	1	≥ 10	15.96
		2	0.01 ≤ X <10	45.70
		3	< 0.01	38.34

Variable Description (unit of measurement)	Level	Category Cut-point	Population Distribution (n=733)
Ergonomist estimated lifting force, time-weighted average (rating score of 0 to 10)	1	≥ 3	6.96
	2	0.01 ≤ X <3	54.71
	3	< 0.01	38.34
Measured peak Lifting force (% time)	1	≥ 2.5	22.10
	2	0.01 ≤ X <2.5	39.56
	3	< 0.01	38.34
Frequency of measured peak lifting force (times/min)	1	≥ 0.7	21.96
	2	0.01 ≤ X <0.7	39.70
	3	< 0.01	38.34
Measured peak lifting force (lbs)	1	≥ 15	23.33
	2	0.01 ≤ X <15	38.34
	3	< 0.01	38.34
Estimated peak lifting force (% time)	1	≥ 2.5	23.06
	2	0.01 ≤ X <2.5	38.61
	3	< 0.01	38.34
Frequency of estimated peak lifting force (times/min)	1	≥ 1.4	14.05
	2	0.01 ≤ X <1.4	47.61
	3	< 0.01	38.34
Estimated peak lifting force (lbs)	1	≥ 2.5	32.06
	2	0.01 ≤ X <2.5	29.60
	3	< 0.01	38.34
Estimated common lifting force (% time)	1	≥ 10	22.37
	2	0.01 ≤ X <10	39.29
	3	< 0.01	38.34
Frequency of estimated common lifting force (times/min)	1	≥ 1.8	26.60
	2	0.01 ≤ X <1.8	35.06
	3	< 0.01	38.34
Estimated common lifting force (lbs)	1	≥ 2	24.28
	2	0.01 ≤ X <2	37.38
	3	< 0.01	38.34
Push/pull force, time-weighted average (% time)	1	≥ 4	7.50
	2	0.01 ≤ X <4	9.14
	3	< 0.01	83.36
Frequency of push/pull force, time-weighted average (times/min)	1	≥ 0.6	7.23
	2	0.01 ≤ X <0.6	9.41
	3	< 0.01	83.36
Measured push/pull force, time-weighted average (lbs)	1	≥ 12	8.05
	2	0.01 ≤ X <12	8.59
	3	< 0.01	83.36
Ergonomist estimated push/pull force, time-weighted average (rating score of 0 to 10)	1	≥ 1.5	9.97
	2	0.01 ≤ X <1.5	6.56
	3	< 0.01	83.47
Measured peak push/pull force (% time)	1	≥ 1	8.05
	2	0.01 ≤ X <1	8.59
	3	< 0.01	83.36
Frequency of measured peak push/pull force (times/min)	1	≥ 0.18	7.37
	2	0.01 ≤ X <0.18	9.28
	3	< 0.01	83.36
Measured peak push/pull force (lbs)	1	≥ 20	7.09
	2	0.01 ≤ X <20	9.55
	3	< 0.01	83.36

Variable Description (unit of measurement)	Level	Category Cut-point	Population Distribution (n=733)
Estimated peak push/pull force (% time)	1	≥ 1.5	7.23
	2	0.01 ≤ X <1.5	9.41
	3	< 0.01	83.36
Frequency of estimated peak push/pull force (times/min)	1	≥ 0.16	7.91
	2	0.01 ≤ X <0.16	8.73
	3	< 0.01	83.36
Estimated peak push/pull force (lbs)	1	≥ 2.5	10.11
	2	0.01 ≤ X <2.5	6.42
	3	< 0.01	83.47
Estimated common push/pull force (% time)	1	≥ 2.6	8.19
	2	0.01 ≤ X <2.6	8.46
	3	< 0.01	83.36
Frequency of estimated common push/pull force (times/min)	1	≥ 0.3	8.46
	2	0.01 ≤ X <0.3	8.19
	3	< 0.01	83.36
Estimated common push/pull force (lbs)	1	≥ 2	9.70
	2	0.01 ≤ X <2	6.83
	3	< 0.01	83.47

Table R8. Description and Distribution of Posture Variables

	Variable Description (unit of measurement)		Category Cut-point	Population Distribution % (n=733)
NECK:				
	Neck extension < -5° and neck flexion ≥10° (% time)	1	≥ 82	33.02
		2	68 ≤ X <82	33.42
		3	< 68	33.56
	Neck extension < -5° and neck flexion ≥ 20° (% time)	1	≥ 66	32.74
		2	48 ≤ X <66	34.92
		3	< 48	32.33
	Neck extension < -5° (% time)	1	≥ 22	34.92
		2	8 ≤ X <22	37.24
		3	< 8	27.83
	Neck lateral flexion ≥ 10° (% time)	1	≥ 23	33.01
		2	11 ≤ X <23	32.33
		3	< 11	34.66
	Neck lateral flexion ≥ 30° (% time)	1	≥ 2	1.51
		2	1 ≤ X <2	5.48
		3	< 1	93.01
	Neck rotation ≥ 10° (% time)	1	≥ 72	33.01
		2	58 ≤ X <72	32.05
		3	< 58	34.93
	Neck rotation ≥ 45° (% time)	1	≥ 10	31.37
		2	3 ≤ X <10	36.30
		3	< 3	32.33
UPPER ARM:				
	Upper arm flexion ≥ 45° (% time)	1	≥ 23	32.47
		2	11 ≤ X <23	34.24
		3	< 11	33.29

	Variable Description (unit of measurement)		Category Cut-point	Population Distribution % (n=733)
	Upper arm extension < -5° and upper arm flexion ≥ 45° (% time)	1	≥ 33	33.56
		2	19 ≤ X <33	33.42
		3	< 19	33.02
	Upper arm extension < -5° and upper arm flexion ≥ 90° (% time)	1	≥ 14	31.51
		2	6 ≤ X <14	33.15
		3	< 6	35.33
	Upper arm flexion ≥ 90° (% time)	1	≥ 3	29.33
		2	1 ≤ X <3	29.06
		3	< 1	41.61
	Upper arm adduction < -5° and upper arm abduction ≥ 30° (% time)	1	≥ 18	31.92
		2	8 ≤ X <18	39.97
		3	< 8	28.10
	Upper arm abduction ≥ 30° (% time)	1	≥ 15	36.29
		2	7 ≤ X <15	31.65
		3	< 7	32.06
	Upper arm abduction ≥ 60° (% time)	1	≥ 6	28.24
		2	2 ≤ X <6	32.61
		3	< 2	39.15
	Upper arm outward rotation < -5° and upper arm inward rotation ≥ 15° (% time)	1	≥ 62	33.42
		2	47 ≤ X <62	33.97
		3	< 47	32.61
	Upper arm outward rotation < -5° and upper arm inward rotation ≥ 45° (% time)	1	≥ 20	35.20
		2	12 ≤ X <20	32.33
		3	< 12	32.47
	Upper arm outward rotation < -5° and upper arm inward rotation ≥ 0° (% time)	1	≥ 15	34.65
		2	7 ≤ X <15	33.42
		3	< 7	31.92
ELBOW:				
	Elbow extension < -5° and elbow flexion ≥ 20° (% time)	1	≥ 92	36.83
		2	83 ≤ X <92	30.01
		3	< 83	33.15
	Elbow extension < -5° and elbow flexion ≥ 100° (% time)	1	≥ 12	36.56
		2	5 ≤ X <12	34.11
		3	<5	29.33
	Elbow flexion ≥ 100° (% time)	1	≥ 12	34.24
		2	5 ≤ X <12	32.74
		3	< 5	33.02
WRIST:				
	Wrist extension ≤ 15° and wrist flexion < 15° (% time)	1	≥ 48	75.85
		2	35 ≤ X <48	15.01
		3	< 35	9.14
	Wrist extension > 45° and wrist flexion ≥ 15° (% time)	1	≥ 19	34.24
		2	10 ≤ X <19	31.11
		3	< 10	34.65
	Wrist extension > 45° and wrist flexion ≥ 45° (% time)	1	≥ 3	28.65
		2	1 ≤ X <3	32.06
		3	< 1	39.29
	Wrist flexion ≥ 45° (% time)	1	≥ 2	6.55
		2	1 ≤ X <2	10.91
		3	< 1	82.54

	Variable Description (unit of measurement)		Category Cut-point	Population Distribution % (n=733)
	Wrist flexion ≥ 15° (% time)	1	≥ 16	36.43
		2	7 ≤ X <16	30.56
		3	< 7	33.02
	Wrist flexion ≥ 45° (% time)	1	≥ 2	6.55
		2	.01 ≤ X <2	11.32
		3	< .01	82.13
	Wrist extension > 15° (% time)	1	≥ 33	34.79
		2	22 ≤ X <33	33.70
		3	< 22	31.51
	Wrist extension > 45° (% time)	1	≥ 2.5	34.52
		3	< 2.5	65.48
	Wrist radial deviation > 5° and wrist ulnar deviation ≥ 10° (% time)	1	≥22	33.29
		2	10 ≤ X <22	34.38
		3	< 10	32.33
	Wrist radial deviation > 5° and wrist ulnar deviation ≥ 20° (% time)	1	≥ 6	33.97
		2	2 ≤ X <6	31.79
		3	< 2	34.24
	Wrist radial deviation > 5° (% time)	1	≥ 2	29.33
		2	.01 ≤ X <2	21.56
		3	< .01	49.11
FOREARM:				
	Forearm pronation ≥ 45° and < 180° and forearm supination ≥ 45° and < 180° (% time)	1	≥55	33.38
		2	40 ≤ X <55	32.28
		3	< 40	34.34
	Forearm supination ≥ 45° and < 180° (% time)	1	≥ 7	32.01
		2	2 ≤ X <7	37.07
		3	< 2	30.92
	Forearm pronation ≥ 45° and < 180° (% time)	1	≥ 48	35.43
		2	33 ≤ X <48	32.15
		3	< 33	32.42

Baseline Findings

Demographic variables were not significantly different between those who had clinical tension neck syndrome and those who did not (Table R 9) Those with tension neck syndrome had lower perceived general health, tended to be in more passive jobs, score somewhat lower on the SF-12 mental health scale (Table R 10). None of the work organizational factors were significantly different between cases and non-cases.

Table R9. Clinical Tension Neck Syndrome. Individual characteristics of the study population at baseline, by dominant hand

		All subjects			Excluded other UEMSD		
Characteristics	**All subjects (n=733)**	**Tension neck syndrome cases (n=38)**	**Non cases (n=695)**	**p-value ***	**TNECK clinical case only[a] (n=27)**	**Non-TNECK cases with no other clinical conditions (n=495)**	**p-value**
Age, mean ± SD	39.5 ± 11.0	41.4 ± 11.1	39.4 ± 11.0	0.26	40.8 ± 11.1	37.7 ± 10.9	0.16
BMI, mean ± SD	27.3 ± 5.8	26.5 ± 6.2	27.3 ± 5.8	0.65	27.0 ± 5.3	26.7 ± 5.5	0.76
Years in current job, median (Q1-Q3)	2.4 (0.7-5.4)	2.8 (0.8-5.1)	2.3 (0.7-5.4)	0.44	3.4 (0.8-5.8)	2.1 (0.6-4.5)	0.15
Gender (% male)	52.3	42.1	52.8	0.2	48.1	57	0.37
Race (% white)	59.5	60.5	59.4	0.89	59.3	58	0.9
% with at least high school education	83.5	86.8	83.3	0.57	85.2	83.6	0.83
% with medical disorders*	19.5	26.3	19.1	0.28	22.2	15.6	0.36
% subjects with hobbies or sports requiring high hand force***	40.4	34.2	40.7	0.43	33.3	41.2	0.42
% subjects with hobbies or sports requiring high repetitive hand activities***	34.8	34.2	34.8	0.94	29.6	34.3	0.61

* p-value comparing the Tension neck syndrome clinical cases with the non-cases. Student's t-test or Wilcoxon rank sum test.

** Medical disorders include diabetes, high blood pressure, gout or thyroid.

***High force hobbies included garden, golf, home fixing, knit/sew, volleyball, weightlifting, woodwork; High repetition hobbies included garden, home fixing, knit/sew, music, video, woodwork

a: clinical Tension neck syndrome with no other clinical condition on either side

Table R10. Clinical Tension Neck Syndrome. Psychosocial, SF-12 and work organization factors at baseline, by dominant hand

	All subjects	All subjects			Excluded other UEMSD		
		Tension neck syndrome cases	**Non cases**	**p-value***	**TNECK clinical case only[a]**	**Non-TNECK cases with no other clinical conditions**	**p-value**
Psychosocial**	N=694	n=36	n=658		n=26	n=469	
High job demands	62.7	50.0	63.4	0.11	46.2	60.1	0.16
High decision latitude	47.7	50.0	47.6	0.78	46.2	50.1	0.69
High job satisfaction	66.7	63.9	66.9	0.72	57.7	71.4	0.13
High social support	49.3	55.6	48.9	0.44	53.8	51.8	0.84
High job security	67.6	61.6	67.9	0.39	57.7	70.1	0.18
High general health	54.0	38.9	54.9	0.06	42.3	60.3	0.07
Job strain quadrants							
Passive job	18.0	13.9	18.2	0.03	19.2	19.0	0.18
Active job	28.4	13.9	29.2		11.5	29.2	
High strain	34.3	36.1	34.2		34.6	30.9	
Low strain	19.3	36.1	18.4		34.6	20.9	
SF-12**	N=627	n=35	n=592				
Low PCS 12	49.8	48.6	50.3	0.84	52.0	54.0	0.82
Low MCS 12	50.6	34.3	50.3	0.06	36.0	52.2	0.11
Work organization	N=725	n=37	n=688		n=26	n=491	
Social contents							
Work team, high coordination	19.2	13.5	19.5	0.21	15.4	18.9	0.52
Work team, minimal to moderate coordination	37.8	51.4	37.1		50.0	38.7	
Individual	43.0	35.1	43.5		34.6	42.4	
Job contents							
Very strong structural restraints	54.2	43.2	54.8	0.12	54.8	43.2	0.16
Strong structural restraints	28.3	43.2	27.5		27.5	43.2	
Very minor to average structural restraints	17.5	13.5	17.7		17.7	13.5	
Pace							
Piece rate or quota	10.3	13.5	10.2	0.41	19.2	9.4	0.19
Machine or line	53.8	43.2	54.4		42.3	55.4	
Self or social/peer	35.9	43.2	35.5		38.5	35.2	
Rotation, % yes	30.6	24.3	31.0	0.39	30.8	29.7	0.91

*p-value from Chi-squared test comparing the tension neck syndrome clinical cases with non-cases.
**% greater or equal to median for psychosocial factors and % less than median for SF-12. Job strain quadrants: Low strain=low demand and high control, High strain= high demand and low control, Active job= high demand and high control, Passive job= low demand and low control.
a: clinical tension neck syndrome with no other clinical condition on either side

For Rotator Cuff Tendinitis (RCT), there were no significant demographic differences between cases and non-cases (Table R11). Cases tended to report a worse psychosocial environment particularly in the areas on decision latitude, job satisfaction, job security and general health. Their jobs were more structurally constraining as well (Table R12).

Table R11. Clinical Rotator Cuff Tendinitis. Individual characteristics of the study population, by dominant hand

		All subjects			Excluded other UEMSD		
Characteristics	**All subjects (N=733)**	**RCT cases (n=55)**	**Non cases (n=678)**	**p-value***	**RCT clinical case only[a] (n=33)**	**Non-RCT cases with no other clinical conditions (n=510)**	**p-value**
Age, mean ± SD	39.5 ± 11.0	41.8 ± 10.4	39.3 ± 11.0	0.11	39.3 ± 10.1	37.8 ± 10.9	0.47
BMI, mean ± SD	27.3 ± 5.8	28.6 ± 6.7	27.2 ± 5.7	0.09	28.5 ± 6.5	26.8 ± 5.5	0.1
Years in current job, median (Q1-Q3)	2.4 (0.7-5.4)	2.6 (1.1-6.9)	2.3 (0.6-5.1)	0.19	2.8 (1.2-8.0)	2.1 (0.6-4.5)	0.15
Gender (% male)	52.3	54.5	52.1	0.72	60.6	57.3	0.71
Race (% white)	59.5	54.5	59.9	0.44	54.5	59.9	0.29
Education (% with at least high school education)	83.5	78.2	83.9	0.27	78.2	83.9	0.73
Medical disorders* (%)	19.5	18.2	19.6	0.8	18.2	19.6	0.80
Hobbies or sports requiring high hand force (%)	40.4	29.1	41.3	0.08	30.3	40.6	0.24
Hobbies or sports requiring high repetitive hand activities (%)	34.8	25.5	35.5	0.13	30.3	34.3	0.64

* p-value comparing the rotator cuff tendinitis clinical cases with the non-cases. Student's t-test or Wilcoxon rank sum test.

** Medical disorders include diabetes, high blood pressure, gout or thyroid.

a: clinical RCT with no other clinical condition on either side

Table R12. Clinical Rotator Cuff Tendinitis (RCT). Psychosocial, SF-12 and work organization factory, by dominant hand

Characteristics	All subjects	All subjects: RCT cases	All subjects: Non cases	All subjects: p-value*	Excluded other UEMSD: RCT clinical case only[a]	Excluded other UEMSD: Non-RCT cases with no other clinical conditions	Excluded other UEMSD: p-value
Psychosocial**	N=694	n=53	n=641		n=32	n=483	
High job demands	62.7	58.5	63.0	0.51	62.5	60.2	0.81
High decision latitude	47.7	35.8	48.7	0.07	28.1	49.5	0.0192
High job satisfaction	66.7	56.6	67.6	0.10	50	71.0	0.0122
High social support	49.3	43.4	49.8	0.37	46.9	51.6	0.61
High job security	67.6	54.7	68.6	0.0374	53.1	70.2	0.0431
High general health	54.0	39.6	55.2	0.0285	43.8	59.8	0.07
Job strain quadrants							
Passive job	18.0	22.6	17.6	0.24	21.9	19.0	0.09
Active job	28.4	17.0	29.3		12.5	28.8	
High strain	34.3	41.5	33.7		50.0	31.5	
Low strain	19.3	18.9	19.3		15.6	20.7	
SF-12**	N=627	n=48	n=579		n=30	n=435	
Low PCS 12	49.8	68.8	48.2	0.0062			0.14
Low MCS 12	50.6	45.8	50.9	0.50			0.88
Work organization	N=725	n=55	n=670		n=33	n=506	
Social contents							
Work team, high coordination	19.2	25.5	18.7	0.45	27.3	18.6	0.46
Work team, minimal to moderate coordination	37.8	36.4	37.9		33.3	39.3	
Individual	43.0	38.2	43.4		39.4	42.1	
Job contents							
Very strong structural restraints	54.2	69.1	53.0	0.0388	69.7	53.6	0.17
Strong structural restraints	28.3	23.6	28.7		21.2	26.7	
Very minor to average structural restraints	17.5	7.3	18.4		9.1	19.8	
Pace							
Piece rate or quota	10.3	3.6	10.9	0.19	6.1	9.3	0.92
Machine or line	53.8	61.8	53.1		57.6	55.5	
Self or social/peer	35.9	34.5	36.0		36.4	35.2	
Rotation, % yes	30.6	36.1	30.1	0.21	30.3	29.4	0.92

*p-value from Chi-squared test comparing the rotator cuff tendinitis clinical cases with non-cases.
**% greater or equal to median for psychosocial factors, and % less than median for SF-12.
a: clinical RCT with no other clinical condition on either side

Subjects with lateral epicondylitis were significantly more likely to be female, older, and white (Table R13). They also reported having less job satisfaction and social support. They also tended to be on piece work or a quota system and more likely to rotate (Table R14).

Table R13. Clinical Lateral Epicondylitis (LEPI). Individual characteristics of the study population, by dominant hand

		All subjects			Excluded other UEMSD		
Characteristics	**All subjects (N=733)**	**Lateral epicondylitis clinical cases (n=38)**	**Non cases (n=695)**	**p-value***	**LEPI clinical case only (n=12)[a]**	**Non-LEPI cases with no other clinical conditions (n=504)**	**p-value**
Age, mean ± SD	39.5 ± 11.0	42.7 ± 8.1	39.3 ± 11.1	0.0167	41.9 ± 10.1	37.8 ± 10.9	0.19
Gender (% male)	52.3	36.8	53.1	0.0508	25.0	56.9	0.0275
BMI, mean ± SD	27.3 ± 5.8	27.6 ± 6.5	27.3 ± 5.8	0.28	27.9 ± 5.5	26.7 ± 5.5	0.48
Race (% white)	59.5	84.2	58.1	0.0014	91.7	58.3	0.0203
Education (% with at least high school education)	83.5	78.9	83.7	0.44	83.5	83.5	0.99
Medical disorders (%)**	19.5	21.1	19.4	0.81	8.3	15.5	0.5
Years in current job, median (Q1-Q3)	2.4 (0.7-5.4)	2.8 (1.0-6.3)	2.3 (0.7-5.1)	0.30	2.6 (0.9-8.2)	2.1 (0.6-4.5)	0.45
Having hobbies or sports requiring high hand force (%)****	40.4	39.5	40.4	0.91	50.0	58.7	0.54
Having hobbies or sports requiring high repetitive hand activities (%)****	34.8	34.2	34.8	0.94	75.0	65.1	0.56

* p-value comparing the LEPI clinical cases with the non-cases. Student's t-test, Wilcoxon rank sum test or Chi-squared test.

** Medical disorders include diabetes, high blood pressure, gout or thyroid.

***Any of the neck and upper extremity MSDs, excluding lateral epicondylitis.

***High force hobbies included garden, golf, home fixing, knit/sew, volleyball, weightlifting, woodwork; High repetition hobbies included garden, home fixing, knit/sew, music, video, woodwork

a: clinical LEPI with no other clinical condition on either side

Table R14. Clinical Lateral Epicondylitis (LEPI). Psychosocial, SF-12 and work organization factors, by dominant hand

		All subjects			Excluded other UEMSD		
Characteristics	**All subjects**	**Lateral epicondylitis cases**	**Non cases**	**p-value***	**LEPI case only[a]**	**Non-LEPI cases with no other clinical conditions**	**p-value**
Psychosocial**	**N=694**	**n=38**	**n=656**		**n=12**	**n=477**	
High job demands	62.7	73.7	62.0	0.15	75.0	60.4	0.31
High decision latitude	47.7	39.5	48.2	0.30	41.7	50.1	0.56
High job satisfaction	66.7	44.7	68.0	0.0031	41.7	71.3	0.0262
High social support	49.3	23.7	50.8	0.0012	25.0	51.6	0.07
High job security	67.6	55.3	68.3	0.10	50.0	70.6	0.12
High general health	54.0	42.1	54.7	0.13	58.3	60.6	0.87
Job strain quadrants							
Passive job	18.0	15.8	18.1	0.39	16.7	18.9	0.71
Active job	28.4	28.9	28.4		33.3	29.4	
High strain	34.3	44.7	33.7		41.7	31.0	
Low strain	19.3	10.5	19.8		8.3	20.8	
SF-12**	**N=627**	**n=36**	**n=591**		**n=12**	**n=430**	
Low PCS 12	49.8	61.1	49.1	0.16	41.7	45.6	0.79
Low MCS 12	50.6	63.9	49.7	0.10	58.3	47.9	0.48
Social contents	**N=725**	**n=37**	**n=688**		**n=11**	**n=500**	
Work team, high coordination	19.2	27.0	18.8	0.45	18.2	19.0	1.00
Work team, minimal to moderate coordination	37.8	32.4	38.1		36.4	39.0	
Individual	43.0	40.5	43.2		45.5	42.0	
Job contents							
Very strong structural restrains	54.2	62.2	53.8	0.11	54.5	53.4	0.18
Strong structural restrains	28.3	32.4	28.1		45.5	27.2	
Very minor to average structural restrains	17.5	5.4	18.2		0.0	19.4	
Pace							
Piece rate or quota	10.3	21.6	9.7	0.07	18.2	9.4	0.53
Machine or line	53.8	48.6	54.1		54.5	55.2	
Self or social/peer	35.9	29.7	36.2		27.3	35.4	
Rotation, yes	30.6	48.6	29.7	0.0146	45.5	29.2	0.24

*p-value from Chi-squared or Fisher exact tests comparing the LEPI clinical cases with non-cases.

**% greater or equal to median for psychosocial factors and % less than median for SF-12. Job strain quadrants: Low strain=low demand and high control, High strain= high demand and low control, Active job= high demand and high control, Passive job= low demand and low control.

a: clinical LEPI with no other clinical condition on either side

Subjects with clinical carpal tunnel syndrome (CTS) were significantly older, had higher BMI, tended to be women, were more likely to have other medical disorders (diabetes, hypertension, thyroid condition). There were no significant differences in race, years on the job, education or hobbies, Table R15. Those with clinical CTS also were significantly more likely to view their jobs as having high job demands and were significantly more likely to report poorer general health than no-clinical case subjects (Table R16) with no clinical conditions. There were no significant differences in SF-12 scores or work organization characteristics.

Table R15. Clinical Carpal Tunnel Syndrome (CTS). Individual characteristics of the study population at baseline, by dominant hand

		All subjects			Excluded other UEMSD		
Characteristics	**All subjects (N=733)**	**CTS cases (n=63)**	**Non cases (n=670)**	**p-value***	**CTS clinical case only[a] (n=48)**	**Non-CTS cases with no other clinical conditions (n=505)**	**p-value**
Age, mean ± SD	39.5 ± 11.0	46.4 ± 10.0	38.8 ± 10.8	<0.0001	45.1 ± 10.4	37.8 ± 11.0	<0.0001
BMI, mean ± SD	27.3 ± 5.8	29.5 ± 6.2	27.1 ± 5.7	0.0049	29.3 ± 5.8	26.8 ± 5.5	0.0021
Years in current job, median (Q1-Q3)	2.4 (0.7-5.4)	3.2 (0.7-6.6)	2.3 (0.7-5.2)	0.39	3.0 (0.6-5.9)	2.2 (0.6-4.6)	0.46
Gender (% male)	52.3	38.1	53.6	0.0186	37.5	56.8	0.0101
Race (% white)	59.5	52.4	60.1	0.15	56.3	58.0	0.81
% with at least high school education	83.5	81.0	83.7	0.57	87.5	83.6	0.48
% with medical disorders*	19.5	30.2	18.5	0.0257	33.3	15.6	0.0019
% subjects with hobbies or sports requiring high hand force***	40.4	39.7	40.4	0.91	60.4	58.8	0.83
% subjects with hobbies or sports requiring high repetitive hand activities***	34.8	31.7	35.1	0.6	68.8	65.7	0.67

* p-value comparing the CTS clinical cases with the non-cases. Student's t-test or Wilcoxon rank sum test.
** Medical disorders include diabetes, high blood pressure, gout or thyroid.
***High force hobbies included garden, golf, home fixing, knit/sew, volleyball, weightlifting, woodwork; High repetition hobbies included garden, home fixing, knit/sew, music, video, woodwork
a: clinical RCT with no other clinical condition on either side

Table R16. Clinical Carpal Tunnel Syndrome (CTS). Psychosocial, SF-12 and work organization factors at baseline, by dominant hand

		All subjects			Excluded other UEMSD		
Characteristics	**All subjects**	**CTS cases**	**Non cases**	**p-value***	**CTS clinical case only[a]**	**Non-CTS cases with no other clinical conditions**	**p-value**
Psychosocial**	N=694	n=60	n=634		n=45	n=467	
High job demands	62.7	73.3	61.2	0.07	76.1	60.5	0.0372
High decision latitude	47.7	48.3	47.6	0.92	47.8	49.8	0.8
High job satisfaction	66.7	65.0	66.9	0.77	65.2	70.9	0.42
High social support	49.3	51.7	49.1	0.70	52.2	51.5	0.93
High job security	67.6	68.3	67.5	0.90	67.4	70.1	0.7
High general health	54.0	30.0	56.3	<0.0001	28.3	60.5	<0.0001
Job strain quadrants							
Passive job	18.0	15.0	18.3	0.26	15.2	18.6	0.15
Active job	28.4	36.7	27.6		39.1	28.9	
High strain	34.3	36.7	34.1		37.0	31.6	
Low strain	19.3	11.7	20.0		8.7	20.9	
SF-12**	N=627	n=53	n=574				
Low PCS 12	49.8	58.5	49.0	0.18	51.2	45.9	0.14
Low MCS 12	50.6	47.2	50.9	0.61	51.2	48.0	0.88
Work organization	N=725	n=61	n=664		n=46	n=501	
Social contents							
Work team, high coordination	19.2	18.0	19.3	0.41	17.4	18.8	0.47
Work team, minimal to moderate coordination	37.8	31.1	38.4		30.4	38.1	
Individual	43.0	50.8	42.3		52.2	43.1	
Job contents							
Very strong structural restrains	54.2	57.4	53.9	0.87	52.2	53.3	0.87
Strong structural restrains	28.3	26.2	28.5		30.4	27.1	
Very minor to average structural restrains	17.5	16.4	17.6		17.4	19.6	
Pace							
Piece rate or quota	10.3	14.8	9.9	0.43	17.4	9.2	0.20
Machine or line	53.8	54.1	53.8		50.0	55.3	
Self or social/peer	35.9	31.1	36.3		32.6	35.5	
Rotation, yes	30.6	36.1	30.1	0.34	34.8	29.7	0.48

*p-value from Chi-squared test comparing the CTS clinical cases with non-cases.

**% greater or equal to median for psychosocial factors and % less than median for SF-12. Job strain quadrants: Low strain=low demand and high control, High strain= high demand and low control, Active job= high demand and high control, Passive job= low demand and low control.

a: clinical CTS with no other clinical condition on either side

Baseline Multivariate Analyses

We used logistic regression to build the multivariate models. We kept age, gender and BMI in all models although they were not always significant. We also included "other clinical UEMSD" in the models. This was done because it is likely that if the subject has one clinical condition, she or he may have altered their work methods or they may be more likely to develop another UEMSD, particularly because they are still at work with the condition. None of the rest of the demographic or psychosocial or work organization variables was statistically significant in the multivariate analyses.

Clinical Tension Neck Syndrome

Table R17 shows the final logistic regression model for baseline clinical tension neck syndrome. None of the work organization or other individual factors was statistically significant when physical load factors were in the model. Having other upper extremity MSD was also not significantly associated with tension neck syndrome with the exposure variables in the model. When job strain was entered into the model, being in an active job compared to a low strain job (High demands-high control compared to low demand-high control) was protective and statistically significant. Neck rotation more than 45 degrees, frequent arm movements more than 20 times per minute and upper arm abduction more than 30 degrees appear to be protective for the neck although a statistically significant exposure-response relationship was not identified. For the arm movement, coding considered any arm movement including when the shoulder was in a relatively neutral posture. It is likely that having 3 variables for job strain reduced the model's ability to achieve statistical significance for exposure-response relationships of the physical load variables which indicate that neck movement in and out of awkward postures may be protective.

Table R17. Baseline Logistic Regression Model for Clinical Tension Neck Syndrome

Effect		OddsRatioEst	LowerCL	UpperCL
Age		1.01	0.98	1.04
Gender	female vs. male	1.06	0.51	2.21
BMI		1.00	0.95	1.06
Frequent arm movement 20+/min vs. <10		0.30	0.09	0.97
Frequent arm movement >10<20/min vs. <10		0.83	0.37	1.88
Neck rotation ≥ 45° >=10% time vs. <3%		0.32	0.12	0.87
Neck rotation ≥ 45°>=3 to <10% time vs. <3%		0.44	0.19	1.00
Upper Arm Abduction >30° >=15% vs. <7%		0.88	0.39	1.98
Upper Arm Abduction >30° >=7% to <15% vs. <7%		0.19	0.05	0.69
1:4-Passive vs. Low Strain		0.54	0.18	1.61
2:4 Active vs. Low Strain		0.25	0.09	0.74
3:4 High strain vs. Low Strain		1.02	0.42	2.48

Dominant Side Clinical Rotator Cuff Tendinitis (RCT)

BMI was associated with RCT and increasing age was marginally significant (Table R18). Having another upper extremity MSD increased the odds of having dominant side RCT. Physical load factors that were associated with RCT included having the upper arm extended above 45^{o} more than 18% of the time compared to none. There was evidence of an exposure-response relationship between increasing duty cycle and RCT. No other variables were statistically significant with these variables in the model.

Table R18. Baseline Logistic Regression Model for Clinical Rotator Cuff Tendinitis

Effect		OddsRatioEst	LowerCL	UpperCL
age		1.01	0.99	1.04
sex	female vs. male	0.78	0.43	1.42
BMI		1.04	1.00	1.09
Upper Arm flex/extension >45^{o} >=18% time vs. none		1.89	1.04	3.42
Duty cycle of forceful exertion >=4% vs 0%		3.13	1.18	8.31
Duty cycle of forceful exertion >0% to <4% vs. 0%		1.73	0.44	6.77
Other_UEMSD		1.98	1.07	3.67

Dominant Side Clinical Lateral Epicondylitis

Lateral epicondylitis was significantly associated with female gender, even when controlling for other individual and physical load variables (Tables R19). In the full model, the highest odds of epicondylitis were associated with having another upper extremity MSD at the same time. Both high social support and being non-white were associated with reduced odds of lateral epicondylitis. Although forearm rotation had been significant in univariate analysis, it was no longer significant in the multivariate models. There was a significant exposure-response relationship with increasing frequency of high forces.

Table R19. Baseline Logistic Regression Model for Clinical Lateral Epicondylitis

Effect		OddsRatioEst	LowerCL	UpperCL
age		1.02	0.99	1.06
sex	female vs. male	2.22	1.04	4.77
BMI		1.01	0.95	1.07
Forearm rotation>45^{o} >=7% time vs. <2%		1.97	0.75	5.14
Forearm rotation>45^{o}>=2% to <7% time vs. <2%		0.73	0.26	2.03
Frequency of forceful exertion >=5/min vs. <0.6/min		4.51	1.34	15.24
Frequency of forceful exertion >=0.6 to <5/min vs. <0.6/min		4.13	1.27	13.42
Other UEMSD		5.18	2.42	11.08
Non-white vs. white		0.25	0.10	0.63
High vs. low social support		0.35	0.15	0.80

Dominant Side Clinical Carpal Tunnel Syndrome

Dominant side clinical carpal tunnel syndrome was significantly associated with increasing age and BMI but not gender. Increasing frequency of high forces and increasing duration of awkward wrist postures both demonstrated an exposure-response relationship to the odds of clinical carpal tunnel syndrome when adjusting for personal factors (Table R20).

Table R20. Baseline Logistic Regression Model for Clinical Carpal Tunnel Syndrome

Effect		OddsRatioEst	LowerCL	UpperCL
age		1.07	1.04	1.10
sex	female vs. male	1.60	0.91	2.81
BMI		1.07	1.03	1.12
Frequency of high force 5+/min vs. <0.6/min		2.86	1.27	6.43
Frequency of high force >0.6<5/min vs. <0.6/min		2.55	1.20	5.40
Wrist flexion >15° or extension>45° for >=19% time vs. <10% time		2.55	1.08	5.99
Wrist flexion >15° or extension>45° for >=10% time to <19% vs. <10% time		2.53	1.09	5.84

Prospective Analyses

Natural Course of RCT and CTS

Because there is little known about the natural course of these disorders in a working population, in Table R21 we mapped out the clinical course for both dominant side shoulder symptoms/rotator cuff tendinitis and carpal tunnel syndrome over a one year period (Silverstein et al 2006). For the shoulder, both those with either symptoms or positive physical findings appeared to more frequently develop rotator cuff tendinitis within one year then those who are asymptomatic and without physical findings. One year incidence of clinical rotator cuff tendinitis was 5.5% 2.9% (about one-third to one-half the incidence of new symptoms) on the right and left respectively, while persistence was 33.3% on both sides. Complete "recovery" from clinical RCT at one year was 39.4% and 52.4% respectively.

Table R21. Summary Table of Prevalence and Incidence of Rotator Cuff Tendinitis and Shoulder Symptoms

Health outcome	Right N (%)	Left N (%)
Prevalence of shoulder symptoms during the past 12 months*		
Total baseline population (N=698)	168 (24.1)	112 (16.0)
Those of the baseline population who attended follow-up, baseline value (N=436)	102 (23.4)	65 (14.9)
1-year follow-up (N=436)	83 (19.0)	70 (16.1)
Prevalence of shoulder symptoms during the past 7 days and 12 months†		
Total baseline population (N=698)		
Those of the baseline population who attended follow-up, baseline value (N=436)	135 (19.3)	85 (12.2)
1-year follow-up (N=436)	81 (18.6)	50 (11.2)
	64 (14.7)	55 (12.6)
Prevalence of rotator cuff tendinitis‡		
Total baseline population (N=698)	53 (7.6)	35 (5.0)
Those of the baseline population who attended follow-up, baseline value (N=436)	33 (7.6)	21 (4.8)
1-year follow-up (N=436)	33 (7.6)	19 (4.4)
Incidence of 12-month symptoms (N=334 (right), 371 (left))	41 (12.3)	44 (11.9)
One-year incidence of clinical stage rotator cuff tendinitis (N=403 (right), 415 (left))	22 (5.5)	12 (2.9)
Subjects not fulfilling symptom criteria and without physical findings (N=298 (right), 351 (left))	6 (2.0)	4 (1.1)
Subjects with physical findings but not fulfilling symptom criteria (N=36 (right), 20 (left))	8 (22.2)	4 (20.0)
Subjects fulfilling symptom criteria but without physical findings at baseline (N=48 (right), 29 (left))	7 (14.6)	4 (13.8)
Persistence of 12-month symptoms (N=102 (right), 65 (left))	42 (41.2)	26 (40.0)
Persistence of clinical stage rotator cuff tendinitis (N=33 (right), 21 (left))	11 (33.3)	7 (33.3)
Complete recovery from clinical stage rotator cuff tendinitis (N=33(right), 21 (left))	13 (39.4)	11 (52.4)

* Denotes pain, stiffness, spasm, inability to raise arm, burning, numbness or tingling with a frequency of at least once a month OR lasting at least 1 week

† Presence of the shoulder problem fulfilling the above 12-month symptom criterion AND shoulder problem during the past 7 days; no additional criterion for intensity, duration or frequency for the symptoms during the past 7 days

‡ Criteria for symptoms as above AND a positive sign in one of the following tests: resisted shoulder abduction, internal rotation, external rotation, or painful arc (in the provocation test reported intensity of pain ≥1 on a scale from 0 to 4)

For carpal tunnel syndrome, Incidence based on symptoms alone was 7.4% and 8.5% for the right and left hands respectively with incidence (including positive electrodiagnostic studies (NCV) at 3.2% and 2.7% respectively. One-year persistence of clinical CTS was 23.3% and 43.8% respectively (Table R22).

Table R22. Prevalence, incidence and persistence of CTS and symptoms of CTS

Health outcome	**Right (%)**	**Left (%)**
Prevalence of hand diagram positive during the past 12 months at baseline (N=372)	16.1	11.6
Prevalence of hand diagram positive during the past 7 days and 12 months at baseline (N=372)	14.8	9.4
Prevalence of subjects with positive electrodiagnostic examination at baseline (N=372)	32.3	16.1
Prevalence of CTS	8.1	4.3
Incidence of 12-month symptoms (N=312 (right), 329 (left))	7.4	8.5
One-year incidence of CTS		
All subjects without 12-month symptoms at baseline (N=312 (right), 329 (left))	3.2	2.7
Subjects with no symptoms and negative electrodiagnostic examination (N=222 (right), 287 (left))	0.9	0.7
Subjects with positive electrodiagnostic examination but without symptoms (N=90 (right), 42 (left))	8.9	16.7
Subjects with current symptoms but negative NCV at baseline (N=25 (right), 19 (left))	8.0	0.0
Persistence of 12-month symptoms (N=60 (right), 43 (left))	23.3	27.9
Persistence of CTS (N=30 (right), 16 (left))	23.3	43.8
Complete recovery from CTS (N=30 (right), 16 (left))	3.3	6.3

Prospective Modeling Analysis

As noted above with the baseline analysis, descriptive statistical analyses were conducted for all potential covariates of interest to determine variability and the need to categorize or dichotomize continuous variables. Chi-square and Student's t-tests were run for all potential confounders to determine if there were statistically significant differences between cases and non-cases. In the prospective analysis, we limited our analysis to those who did not change jobs during the course of the study. This resulted in creating slightly different cut-points for physical load variables due to changes in the population distribution. Kaplan-Meier curves were computed for all covariates. All covariates that were statistically significant at $\leq$0.10 in univariate analyses were then entered into a Cox proportional hazards model one at a time and the effect on the outcome of interest was assessed. The proportional hazards assumption was tested for by assessing the correlations between the rank time and the Schoenfield residuals for each covariate. Squared multiple correlations (SMC) were examined for multicolinearity in the multivariate model. All analyses were completed with SPSS version 15.0

For incident cases of tension neck syndrome, there was increased risk with increasing age, but no significant effects of gender or BMI (Table R23). The only physical load variables that were significant predictors were the protective effect of using a forceful pinch grip and the increased risk with moving the upper arm more in and out of rotation more than 48.5% of the time. At first glance, the latter finding is inconsistent with the baseline finding that arm movement appears to be protective. At baseline the finding was related to a much shorter percent of the work time whereas when the posture is maintained for more than half the time, as with upper arm rotation in the prospective analysis, the risk increases.

Table R23. Predictors for Incident Clinical Tension Neck Syndrome
48 cases

	HR	Lower CL	Upper CL
Age (years)	1.04	1.01	1.07
Gender (female)	1.19	0.67	2.12
Any pinch grip force (>2lbs), time weighted average	0.39	0.18	0.88
Upper arm outward rotation <-5° and upper arm inward rotation ≥ 15° at ≥ 48.5percent time	2.10	1.01	4.34

There were only 28 incident cases of dominant side clinical rotator cuff tendinitis (Table R24). Increasing age was a significant predictor for rotator cuff tendinitis. Additionally, having another clinical upper extremity musculoskeletal disorder increased risk for rotator cuff tendinitis almost three-fold. Reporting high social support increased risk over two-fold. Both upper arm flexion of 45+ degrees for 11+ percent of the time (HR 3.62, CI 1.09, 12.02) and upper arm abduction of 30+ degrees for 6+ percent of time were statistically significant, but were too correlated to be in the same model.

Table R24. Predictors for Dominant Side Rotator Cuff Syndrome
28 cases

	HR	Lower CL	Upper CL
Age (years)	1.08	1.02	1.14
Gender (female)	1.99	0.78	5.12
Other clinical case during study period	2.83	1.27	6.31
High job satisfaction	2.32	1.03	5.24
Upper arm abduction ≥ to 30 degrees (≥6 %time)	6.48	1.49	28.11

There were 29 incident cases of dominant side lateral epicondylitis (Table R25). Increasing age was a marginally significant predictor but gender and BMI were not. Those with other UEMSDs were at increased risk to develop dominant side lateral epicondylitis. There was also an exposure -response relationship identified with increasing percent time in internal and external rotation more than 62% of the time.

Table R25. Predictors for Dominant Side Clinical Lateral Epicondylitis
29 cases

	HR	Lower CL	Upper CL
Age (years)	1.03	0.98	1.07
Gender (female)	1.84	0.83	4.09
Other clinical case during study period	2.43	1.11	5.30
Frequency of shoulder movements ≥3 times per minute	3.01	1.13	8.06
Upper arm outward rotation <-5° and upper arm inward rotation ≥ 15°			
≥ 48 and < 62 percent time	1.72	0.54	5.46
≥ 62 percent time	2.76	1.00	7.65

There were 28 incident cases of clinical carpal tunnel syndrome. Increasing BMI was a significant predictor and increasing age was a marginally significant predictor for CTS (Table R26). The only physical load factor that remained in the model was percent time in forceful exertions (duty cycle) with an almost four-fold increase for duty cycle of 2 percent time or greater.

Table R26. Predictors for Dominant Side Carpal Tunnel Syndrome
28 cases

	HR	Lower CL	Upper CL
Age (years)	1.02	0.98	1.05
Gender (female)	1.21	0.57	2.60
BMI	1.10	1.04	1.16
Duty cycle of forceful exertions (% time)			
< 2 percent time	--		
≥ 2 percent time	3.80	1.37	10.55

Consortium UEMSD Results

The phase one study of data sharing feasibility between NIOSH WMSD consortium members revealed many areas for future collaboration between members. Table R27 in Appendix C summarizes our findings from self-report, physical exam, nerve conduction and physical exposure by body part.

For all consortium members, location of symptom and current (last 7 days) symptom severity is collected as well as consensus physical exam findings for tension neck, rotator cuff tendinitis, bicipital tendinitis, lateral and medial epicondylitis, hand/wrist tendinitis and DeQuervain's tendinitis. Hand activity level (HAL) is collected by all consortium members along with object weights. Most consortium members may also have comparable measures for hand grip force and posture parameters for the shoulder, elbow, forearm and hands/wrists.

Further discussion is needed to fully appreciate the level of data sharing feasibility that exists between consortium members. Three consortium members are relatively new to the consortium and their exposure analysis plans were not complete at the time of this review. It is our recommendation that the NIOSH WMSD consortium continue to meet to discuss further consensus areas as well as to discuss the logistics of implementing a data sharing agreement between members, and to test combining relevant data elements (with no personal identifying information). Each member will need to discuss human subjects issues with their own institutional review boards before any actual merging of data is possible.

H. DISCUSSION

This study examined the relationships between a variety of individual, psychosocial and physical load variables collected at the individual level with clinical outcomes for neck and upper extremity disorders: tension neck syndrome, rotator cuff tendinitis, lateral epicondylitis and carpal tunnel syndrome. The population studied was diverse in gender, age and cultural backgrounds as well as job related factors. Both cross-sectional and prospective study results are available. Over the course of the study, a large number of subjects were lost to follow-up due primarily to the economic recession that hit manufacturing industries hard. Very few "new" full-time permanent employees" were available for study. Study participation was primarily restricted by the employers due to the amount of time subjects would be off the job every four months. Persistence of the MSDs found in this study of actively working people is consistent with the workers compensation data from Washington State, demonstrating a significant burden to employees, employers, families and society.

Nonetheless, we were able to identify areas of significant risk for workers at baseline and prospectively, particularly related to the duration (duty-cycle) or frequency of forceful exertions and some awkward postures. Exposure response relationships between upper extremity MSDs and physical load factors were identified for all four clinical conditions in the baseline analyses and with lateral epicondylitis in the prospective analysis. This new knowledge should help us to develop more focused and predictive exposure assessment instruments for practitioners to use to reduce upper extremity MSDs in the workplace.

Multivariate analysis identified slightly different factors associated with each of these clinical conditions at baseline and for incident cases over the course of three years.

Important findings from the multivariate analyses include:

Tension Neck Syndrome

- Age was of borderline significance in the baseline prevalence analysis and was a significant predictor in the prospective analysis. Neither gender or BMI were significant
- Being in a psychosocially active job (high demands-high control) was protective compared to being in a low strain job in the baseline analysis but was not significant in the prospective analysis
- Movement (neck rotation, frequent arm movement) appeared to be protective in the baseline analysis whereas maintaining the same shoulder rotation more than 48% of the time significantly increased risk in the prospective analysis.

Rotator Cuff Tendinitis

- Age was of borderline significance in the baseline prevalence analysis and was a significant predictor in the prospective analysis. Gender was not significant in either analysis. BMI was significant in the baseline analysis but not in the prospective analysis
- Having another upper extremity MSD increased risk in both analyses
- No psychosocial factors were identified
- The duration of upper arm flexion/extension were associated with increased risk in both the baseline and prospective analyses
- There was an exposure-response relationship observed between increased duration of duty cycle and rotator cuff tendinitis at baseline.
- The small number of incident cases decreased our ability to identify other significant predictors in the prospective analysis.

Lateral Epicondylitis

- Increasing age was marginally significant in both the baseline and prospective analyses whereas female gender was significant in the baseline but not the prospective analysis. BMI was not significant in either analysis
- Having another upper extremity MSD significantly increased risk in both analyses
- Being "non-white" as well as having high social support were protective in the baseline analysis but non-significant in the prospective analysis
- In the baseline analysis, there was a significant exposure-response relationship with increasing frequency of high forces and with percent of time in forearm rotation more than 45 degrees. In the prospective analysis, there was increased risk of lateral epicondylitis with duration of upper arm rotation (exposure response) and with frequency of shoulder movements.

Carpal Tunnel Syndrome

- Increasing age and BMI were associated with carpal tunnel syndrome in both the baseline and prospective analyses whereas gender was not significant in either analysis
- There was an exposure-response relationship with increasing frequency of high force and duration of wrist flexion-extension in the baseline analyses. In the prospective analysis, percent of duty cycle spent in forceful exertions was a predictor for CTS. Thus either frequency or duration of forceful exertions appears to be strong predictors for CTS.

Loss to follow-up due largely to an economic downturn reduced our ability to test a variety of exposures prospectively. Work with the WMSD consortium identified areas where data could be combined at some point if the will and resources were available. The promising findings of our study suggest the importance of supporting expansion where possible. This study supports the need for testing revised risk assessment models for practitioners.

When physical load variables were in the multivariate models, with the exception of lateral epicondylitis, females were not at increased risk. Risk did increase with BMI for carpal tunnel syndrome and age was of borderline significance with most conditions.

Melchior et al (2006) reported from a French surveillance program, physician diagnosed upper extremity disorders that 11.3% of men and 15.1% of women were so diagnosed, 1.4 to 2.1 times more frequent among men and women working in manual jobs. Worker reported exposures were significantly associated with rotator cuff syndrome and carpal tunnel syndrome. The authors estimated that after adjusting for personal factors, 23.8% in men and 31.4% in women were preventable by having no repetitive or forceful movements. The worker reported exposures that predicted clinical cases are consistent with our observed or measured exposures, particularly with respect to duration and frequency of forceful exertions.

Tension Neck Syndrome

Brandt et al (2004), found associations between clinical cases of tension neck syndrome in computer workers increasing hours of mouse use. Relative risk for new neck pain increased from 1.5 for 15+ hours of keyboard use to 2.4 for 30+ hours of keyboard use. This is consistent with our findings that active movement of the shoulder/arm/ neck, rather than static loading, decrease risk.

Rotator cuff tendinitis

Palmerud et al (2000) identified increased intramuscular pressures in the infraspinatuus and supraspinatus muscles exceeding levels of reduced recovery and impaired blood flow at moderately elevated levels. Hand load did not appear to be as important as postural load. This is consistent with our baseline and prospective multivariate analyses. Melchior's (2006) self-reported risk factors for the shoulder were related to 2 or more hours of exposure to elevated shoulder postures (25% of the time). We found elevated risk at 18% of the time at baseline and 11% of the time prospectively. This suggests elevated shoulder postures should be reduced to less than 10% of the work day at a minimum.

Lateral Epicondylitis

Shiri et al (2006) reported an interaction between repetitive movements of the arms and forceful activities for the risk of possible or definite lateral epicondylitis in a Finnish population study. These findings are consistent with what we found in the present study: frequency of forceful exertions more than 3/minute and frequency of shoulder movements were important risk factors for lateral epicondylitis. This was also consistent with the findings of repetitive hand activity and increased age in a small prospective study by Werner et al (2005). They also help build on the findings of Haahr and Anderson (2003) that looked at the combined effect of posture force and repetition in a physical strain index.

Carpal Tunnel Syndrome

Ettema et al (2006) reported possible mechanisms for CTS being the shredding of tendon tissue due to shear forces in repetitive activities. Melchior (2006) found associations with forceful and repetitive movements, vibration and wrist flexion more than 2 hours per day risk factors for women but not for men. In this study, these were significant risk factors for CTS, with exposures increasing risk at more than 1% of the duty cycle.

In a recent review of CTS and occupation, Palmer et al (2006) found increased risk for use of regular and prolonged hand-held vibratory tools and substantial evidence for high risk from prolonged and highly repetitious flexion/extension of the wrist especially with a forceful grip. Although we did not formally evaluate vibration exposure, we found exposure response relationships with repetitive hand force and flexion extension in the baseline cross-sectional analysis and with increase in duty cycle with frequency of high force in the prospective analysis..

In addition to psychological factors, Leclerc et al (2001) found an association between forceful movements and both carpal tunnel syndrome and lateral epicondylitis. The physical load factors were consistent with our findings. Rocquelaure et al (2002) noted the difference in risk factors identified with incident cases compared to those with prevalent cases. In some ways this might be related to the dynamic work environment, even in a she factory. We also had different risk factors identified in the prospective analyses compared to baseline. However his may be due to the smaller number of people available for the prospective study.

The inter-rater testing we did for the different exposure and health data collection aspects of this study lend confidence to our belief that it is possible to develop and use less labor intensive means of health and exposure assessment for practitioners as well as future studies. The variability in exposures we found for individuals "doing the same job" speaks to the need to measure a few things in everyone rather than extreme detail in a few to represent the many. This is an area of extreme importance for further development if we are to have a significant impact on reducing these disorders in the workplace.

One of the major limitations of this study was the loss to follow-up, thereby reducing our ability to test a number of plausible exposure response relationships. This speaks to the need for combining data where possible with other consortium members where there is comparability in exposure and outcome variables (see Table R10). With the vast amount of data collected by the various consortium members, it would behoove NIOSH and the research community to find the resources for making such collaboration possible. Upper extremity MSDs remain an extreme burden on workers, employers and society. By reducing the kinds of physical loads identified in this study, the society could go a long way toward reducing injury, disability, lost skill and productivity.

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INCLUSION OF GENDER AND MINORITY STUDY SUBJECTS

TOTAL ENROLLMENT REPORT: Number of Subjects Enrolled by Ethnicity and Race

Ethnic Category	Sex/Gender Females	Males	Unknown or Not Reported	Total
Hispanic or Latino	41	55		96 **
Not Hispanic or Latino	350	349		699
Unknown (Individuals not reporting ethnicity)				
Ethnic Category: Total of All Subjects*	391	404	0	795 *
Racial Categories				
American Indian/Alaska Native	10	18		28
Asian	82	59		141
Native Hawaiian or Other Pacific Islander				
Black or African American	13	18		31
White	241	244		485
More than one race				
Unknown or not reported	45	65		110
Racial Categories: Total of All Subjects*	391	404	0	795 *

HISPANIC ENROLLMENT REPORT: Number of Hispanics or Latinos Enrolled

Racial Categories	Females	Males	Unknown or Not Reported	Total
American Indian or Alaska Native				
Asian				
Native Hawaiian or Other Pacific Islander				
Black or African American				
White				
More Than One Race				
Unknown or not reported	41	55		96
Racial Categories: Total of Hispanics or Latinos**	41	55	0	96 **

INCLUSION OF CHILDREN

No children were involved in this study.