Upper Limb Musculoskeletal Disorders: Quantifying Risk Factors

Final Report

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Abstract

A large scale, multi-site prospective cohort study of carpal tunnel syndrome (CTS) and other distal upper extremity (DUE) muscle-tendon disorders (MSDs) was incepted in 2002 with follow-up of the workers through 2009. The primary aims of the study were to quantify relationships between job physical factors and risk of CTS, as well as other DUE muscle-tendon disorders.

A total of 1,205 workers from 21 different industries in three states (WI, IL and UT) were enrolled in the study. Overall participation rate was 81.4%. Complete baseline data were available on 1,099 workers and complete follow-up data on 1,065 workers with a total follow-up of 3,385.7 person-years. To date data have been analyzed on 536 workers and are reported here.

All workers were rendered a questionnaire, structured interview, physical examination and bilateral nerve-conduction study (NCS) at the baseline to document and quantify demographic data, social history, psychosocial factors, past medical history, and CTS and other DUE muscle-tendon disorders status at the time of enrollment. A comprehensive job physical exposure assessment was made for each worker using worker interview, observations of job, measurements of job physical exposure variables and videotaping of the job. The cohort was followed monthly to ascertain CTS and other DUE muscle-tendon disorders status. Approximately every six months, those workers who were symptomatic were administered follow-up NCS tests. Workers were followed quarterly to ascertain a change in job physical exposure. The health outcome assessment team and job physical exposure assessment team were blinded to each other. CTS and lateral epicondylitis were analyzed for the first lifetime occurrence for each disease. First occurrence of any distal upper extremity disorder was analyzed in a virgin cohort with no prior history of distal upper extremity disorders (Any DUE MSD).

At baseline point prevalence was 10.3% for CTS (symptoms + abnormal NCS), 14.9% for lateral epicondylitis and 35.8% for any DUE MSD; and lifetime prevalence was 19.8%, 23.1% and 56.5%, respectively. During an average of 38.2 months of follow-up there were 35 new CTS cases (10.3% of females and 4.5% of males). The incidence rates for CTS, lateral epicondylitis and any DUE MSD were 2.55, 5.75, and 13.67 per 100 person-years respectively. The multivariate Cox regression model with time-varying covariates that predicted increased risk of CTS included the Strain Index (SI) score > 6 (p = 0.008) BMI > 35kg/m^2 (p <0.001), a diagnosis of one or more DUE muscle-tendon disorders (other than CTS) at baseline (p = 0.021), self-reported rheumatoid/inflammatory arthritis (p =0.007), gardening (p = 0.007), and feelings of mental exhaustion (p 0.035). SI scores demonstrated a dose-response relationship up to a SI score of 24 and two SI score categories, > 12 to ≤ 18 and > 18 to ≤ 24, had 3.7- and 9.1-fold increased risk (HR). There was no evidence of association between TLV for HAL as published and risk of CTS (p = 0.25), however a simplified, two-category model for the TLV for HAL (peak force/(10-HAL) raised from 0.78 to 0.84) showed evidence of association (p = 0.04) with a HR of 2.06 (95% CI = 1.04-4.10).

For lateral epicondylitis the multivariate Cox regression model with time-varying covariates that predicted increased risk included Strain Index (SI) score > 8 (HR = 1.8, 95% CI = 1.02-3.16, $p \leq 0.043$), age > 35, playing baseball, and feelings of depression. The TLV for HAL predicted increased risk of lateral epicondylitis ($p = 0.028$) for exposure above TLV (HR = 1.68, 95% CI = 0.87-3.24, $p = 0.122$) but reduced risk for exposure above AL and below TLV (HR = 0.7, 95% CI = 0.29 - 1.69, $p = 0.423$).

In the adjusted models for any DUE MSD, variables that predicted increased risk included worker peak force rating > 5 on Borg CR-10 scale, efforts/min > 22, Strain Index (SI) score > 7 calculated using worker peak force rating (overall $p = 0.004$) (HR = 1.41, 95% CI = 0.50 – 3.97, $p = 0.511$ for SI > 7 and ≤ 36, HR = 2.88, 95% CI = 1.02-8.09, p 0.046), simplified 2-category TLV for HAL with TLV raised to 0.87 (HR = 1.73, 95% CI 1.10-2.71, $p = 0.017$), age > 38 years and female gender.

This study suggests a multifactor etiology for risk of CTS, lateral epicondylitis and any DUE MSD in general. Job physical factors play an important role. The results of this study should be useful to employers, engineers, and occupational health and safety professionals to analyze and design jobs to reduce cases of CTS, lateral epicondylitis as well as any DUE MSD.

Executive Summary

Highlights/Significant Findings

1. Distal upper extremity (DUE) musculoskeletal disorders (MSDs) are common among U.S. workers. In this study at the time of enrollment lifetime prevalence was 19.8% for CTS, 21.8% for lateral epicondylitis and 56.5% for one or more DUE muscle-tendon disorders including CTS.

   The incidence rate for CTS during this study was 2.55 per 100 person-years, for lateral epicondylitis the incident rate was 5.75 and for first lifetime occurrence of any DUE MSD, the incident rate was 13.67 per 100 person-years.

2. Biomechanical stresses play a key role in the onset of CTS, lateral epicondylitis and any DUE MSD (*Any DUE MSD refers to first occurrence of any distal upper extremity disorder and was analyzed in a virgin cohort with no prior history of distal upper extremity disorders*)

3. There appears to be an interaction among different job physical exposure variables. While peak force and repetition are associated with increased risk, deviated hand/wrist posture showed no increased risk.

4. Among different measures of job physical exposure, the Strain Index best predicted the onset of CTS, lateral epicondylitis and any DUE MSD. A Strain Index score (SI score) of greater than 6 was associated with an increased risk of CTS and there was a strong dose-response relationship.

5. TLV for HAL as prescribed was not associated with increased risk of CTS or any DUE MSD. However, a simple, 2-category TLV for HAL with raised TLV was predictive of CTS, lateral epicondylitis and any DUE MSD.

6. Morbidly obese workers (BMI > 35) are at an increased risk for CTS. Older workers are at an increased risk for lateral epicondylitis (age > 35 years) and any DUE MSD (age > 38 years). Female workers are at a higher risk for any DUE MSD.

7. Prevalence of inflammatory arthritis (including rheumatoid arthritis) and past history of DUE muscle-tendon disorders (other than CTS) were predictive of future incident cases of only CTS. Past history of DUE muscle-tendon disorders did not increase risk for either lateral epicondylitis or any DUE MSD.

8. Gardening (outside of work physical activities) showed evidence of association with CTS while playing Baseball increased risk for lateral epicondylitis. None of the hobbies or physical activities studied were associated with first occurrence of any DUE MSD.

9. There was increased risk of CTS with self-reported feelings of mental exhaustion after work and increased risk of lateral epicondylitis with feelings of depression. None of the psychosocial factors studied were associated with any DUE MSD.

10. This study did not find evidence of association between gender, age and diabetes and CTS. Similarly, there was no evidence of association between education level and smoking and increased risk of CTS.

Translation of Findings

This study suggests a multifactor etiology for risk of CTS. Biomechanical stressors on the job are associated with an increased risk of CTS as well as other distal upper extremity muscle-tendon disorders. Workers who are morbidly obese, have inflammatory arthritis, or have past history of distal upper extremity muscle-tendon disorders (other than CTS), are involved in gardening (outside of work), or suffer from feelings of mental exhaustion after work are at an increased risk of developing carpal tunnel syndrome. The overall findings of this study have implications for proactive prevention programs for CTS and other distal upper extremity muscle-tendon disorders. It appears that addressing job physical demands should be effective in prevention of CTS and other distal upper extremity soft-tissue disorders.

Among different job analysis tools studied, the Strain Index was found to be most predictive of future cases of CTS, lateral epicondylitis and any distal upper extremity musculoskeletal disorder. The study found that the Strain Index was effective in quantifying job physical demands associated with manufacturing and assembly jobs.

Certain health issues such as smoking, diabetes and cholesterol were not associated with future cases of CTS. Similarly, hobbies and physical activities outside of work, except gardening, were not predictive of future cases of CTS. Psychosocial factors other than feelings of mental exhaustion were not associated with increased risk. This would suggest that primary efforts should be directed towards addressing job physical demands to prevent CTS and other distal upper extremity soft-tissue disorders..

Outcomes/Relevance/Impact

The results of this study suggest that the five most important predictors of future CTS are (i) job physical demands, (ii) obesity, (iii) inflammatory arthritis and past history of other distal upper extremity muscle-tendon disorders, (iv) self-reported feelings of mental exhaustion after work, and (v) gardening. The results suggest that there might be interactions between these predictors and these interactions may be more effective in predicting future cases of CTS. This study did not have enough statistical power to study these interactions. Future research studies should be designed to address these interactions.

The results of this study should be useful to employers, engineers, and occupational health and safety professionals who analyze and design jobs to reduce work-related cases of CTS and other distal upper extremity musculoskeletal disorders,.

Accurately quantifying job physical exposure and assigning physical exposure to a worker was the biggest challenge that this study faced. The study found that there were frequent and often significant changes in job physical exposure within a given day and week as well as within and between months of follow up. Accurately accounting for physical exposure requires substantial manpower and time, an issue that the future studies should carefully consider. More importantly, new strategies and procedures are needed for assigning job physical exposure at the worker level particularly for those workers whose exposure varies during a day.

1. Study Goal, Hypotheses and Specific Aims

Goal: Perform a prospective cohort study of Distal Upper Extremity Musculoskeletal Disorders (MSDs) in order to quantify risk.

1.1. Hypotheses And Specific Aims

Hypothesis 1: There is a relationship between measured Job Physical Exposures and subsequent risk for Distal Upper Extremity (DUE) musculoskeletal symptoms and aggregate disorders (MSDs) in a cohort.

H_1 1A. There is a relationship between Job Physical Exposures and the subsequent risk for distal upper extremity musculoskeletal *symptoms*.

H_1 1B. There is a relationship between Job Physical Exposures and the subsequent risk for total diagnosable DUE *MSDs* (analyzed in composite).

Hypothesis 2: There is a relationship between Job Physical Exposures and the subsequent risk for specific DUE MSDs

H_1 2A. There is a relationship between Job Physical Exposures and Carpal Tunnel Syndrome

H_1 2B. There is a relationship between Job Physical Exposures and Lateral Epicondylitis.

H_1 2C There are relationships between Job Physical Exposures and other specific disorders (e.g., deQuervain's stenosing tenosynovitis, other extensor tenosynovitides etc.).

1.2. Specific Aims

1. Measure Job Physical Exposures on 600 workers (200 each in low, medium and high exposure categories) blinded to health outcomes data:
    a. Measure Job Physical Exposures at baseline and record changes in exposures monthly over a 3-year follow-up period.
    b. Quantify Job Physical Exposures as much as practically possible, such as force, repetition, percent duration of exertion, posture, hours of exposure, etc.
    c. Analyze exposures with job analysis methods particularly including ACGIH TLV for Hand Activity Level (HAL), the Strain Index, and the Washington State Checklist (WISHA).
    d. Classify exposures into Low, Medium and High exposure categories

2. Measure the occurrence of disease in the population, blinded to the exposure status:
    a. Obtain baseline questionnaire data, structured interviews, and physical examinations on all enrollees.
    b. Obtain Nerve Conduction Velocity measurements in those with CTS-like symptoms at baseline and also upon CTS-like symptoms reporting during monthly follow-up of the cohort.
    c. Monitor, monthly, the population for the occurrence of symptoms, injuries, and relevant diseases and render physical examinations for those with new or changes in symptoms.
    d. Perform exit questionnaires, structured interviews, and physical examinations at the termination of the study (or upon termination of employment).

3. Assess relationships between the Job Physical Exposures and the Health Outcomes
    a. Measure the prevalences of MSDs and symptoms in the assembled cohort at baseline.
    b. Measure the incidences of MSDs and symptoms at one year and the midpoint for the purposes of potential additional enrollments if trends suggest inadequate sample size(s).
    c. Measure the incidence rates for symptoms, all disorders (aggregate) and specific disorders at the study termination.
    d. Assess exposure-symptoms relationships, exposure-disorder relationships in aggregate and exposure-specific disorder relationships.

4. Validate the existing job analysis methods, including the ACGIH TLV for HAL, Washington State checklist and the Strain Index.

2. Methods

This study was approved by the Institutional Review Board of the University of Wisconsin-Milwaukee (#03.02.059).

2.1. Research Teams:

The research group consisted of investigators located in Utah and Wisconsin. Each location had two teams: (i) Health Outcome Assessment Team and (ii) Job Physical Exposure Assessment Team. The Health Outcome Assessment Teams and Job Physical Exposure Assessment Teams were blinded to each other. A third team, Data Compilation and Statistical Analysis Team was located in Utah. A team in Wisconsin in collaboration with the team in Utah complied and preformed relevant statistical analyses on the combined data from two sites.

The Job Physical Exposure Assessment Teams enrolled subjects in the study (in Utah subjects were enrolled by the Health Outcome Assessment Team), performed baseline job physical exposure assessments, conducted quarterly follow-up of the cohort to determine changes in job physical exposure, analyzed job physical variables to quantify job physical exposures and computed metrics of job physical exposure.

The Health Outcome Assessment Team administered the baseline questionnaires, structured interviews, physical examinations, nerve conduction studies (NCS), and followed the workers monthly to assess incident cases for various distal upper extremity (DUE) symptoms and disorders, status of prevalent cases and administered follow-up NCS tests.

Figure 2.1 depicts the sequencing of data collection.

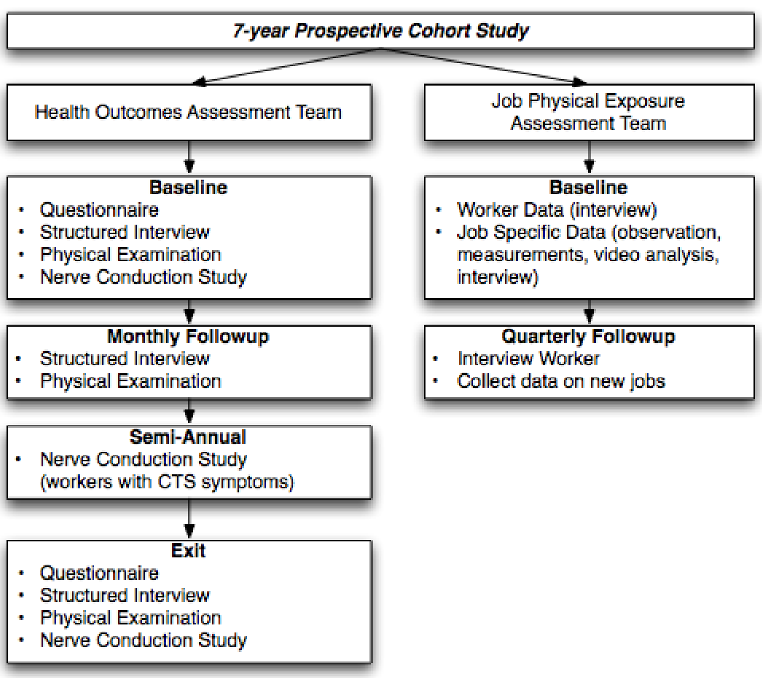

Figure 2.1: Data Collection Sequencing.

2.2. Worker and Company Participation in the Study:

2.2.1. Participating Companies and Procedure for Enrolling Subjects:

Workers for the study were recruited from twenty-three diverse production facilities of twenty-one employers located in Midwest, and Western USA (Table 2.1). Workers at these facilities performed a variety of operations including (i) poultry processing, (ii) manufacturing and assembly of animal laboratory testing equipment, (iii) small engine manufacturing and assembly, (iv) small electric motor manufacturing and assembly (< 1.5kW), (v) commercial lighting assembly and warehousing, (vi) electrical generator manufacturing and assembly, (vii) metal automotive engine parts manufacturing (three facilities), (viii) plastic and rubber automotive engine parts manufacturing and assembly, (ix) glass window and door manufacturing and assembly, (x) private label food and disposer bags manufacturing, (xi) Fabrics & filaments for papermaking industry manufacturing, (xii) industrial electric heaters, sensors and controllers manufacturing and assembly, (xiii) meat processing, (xiv) airbag manufacturing, (xv) undergarment sewing, (xvi) cabinetry manufacturing, (xvii) door manufacturing, (xviii) health care devices manufacturing and (xix) custom aluminum parts manufacturing.

The goal was to involve companies with low, medium and high job physical demands such that one-third of workers were enrolled into each exposure group. In all twenty-three facilities open meetings were arranged by facility management. During these meetings the research team had an opportunity to explain the study and invite workers to participate. Additionally, in a few companies, management, safety department employee representatives and research team members contacted potential subjects and asked for their participation in the study. In all twenty-three facilities, fliers were placed on bulletin boards in the facilities to notify the workers that the research was being conducted in the facility. Irrespective of the method employed for recruitment, principal investigators or other members of the research team met with potential subjects to explain the study and seek their formal participation through a signed consent form. Workers were allowed to withdraw from the study at any time throughout the study period without any pressure or penalty. None of the enrolled subjects withdrew from the study. A total of 1,205 of 1,498 workers attending (80.4%) consented to participate (Table 2.1) (overall participation rate is unclear as the researchers only had access to those willing to attend the meetings, although it is believed to be more than 50%).

2.2.2. Subject Inclusion and Exclusion Criteria:

Subjects were between 18 and 62 years of age at the time of enrollment. A few older subjects who planned to continue their employment beyond the age of 65 were also enrolled. No subject was excluded based on sex, race, ethnicity, or physical or mental disorders unless the subject (i) could not give informed consent, (ii) did not speak either English or Spanish, (iii) was planning to retire within the next 4 years, (iv) had major upper limb deformities including amputations, and/or (v) were working on the overnight shift (i.e. third shift workers). Subjects received their regular wages from the participating companies; no additional monetary benefits were provided for participation in the study. All production workers attending the meetings were eligible to participate in the study with the exception of those workers who were employed as (i) supervisors, (ii) clerical workers, (iii) maintenance/mechanics or (iv) forklift truck drivers. These workers were excluded because of at least one of the following: there would likely be frequent and unpredictable changes in job physical exposures, the SI and ACGIH for TLV were not primarily developed to measure these workers, cycle times were extremely long and/or workers could not readily be videotaped.

Table 2.1: Types of industries participating in the study and enrollment in each plant

	Number of Workers					
State & Employment Setting	**Contacted (A)**	**Consented (B)**	**Ineligible Before Consent (C)**	**Ineligible after Consent (D)**	**Enrolled (E)**	**Participation Rate (%) (E/A)x100**
Wisconsin						
Poultry Processing	87	53	0	0	53	61
Metal automotive parts manufacturer (Plant #1)	45	41	0	0	41	91
Metal automotive parts manufacturer (Plant #2)	42	40	0	0	40	95
Metal automotive parts manufacturer (Plant #3)	11	10	0	0	10	91
Glass window & door manufacturer*	54	48	0	6	42	78
Manufacturing & assembly of animal testing equipment	37	30	0	0	30	81
Small engine manufacturing & assembly	92	89	0	4	85	92
Small electric motor manufacturing & assembly (< 1.5KW)	229	158	28	3	155	68
Commercial lighting manufacturing warehousing	185	144	13	3	141	76
Electric generator manufacturing & assembly	111	59	8	5	54	49
Plastic & rubber automotive parts manufacturing & assembly*	55	48	0	0	48	87
Private label food & disposer bags manufacturing*	82	74	0	3	71	87
Fabrics & filaments manufacturing for papermaking industry*	38	35	0	0	35	92

* Not included in analyses reported in this report

Table 2.1 continued: Types of industries participating in the study and enrollment in each plant

State & Employment Setting	Contacted (A)	Consented (B)	Ineligible Before Consent (C)	Ineligible after Consent (D)	Enrolled (E)	Participation Rate (%) (E/A)x100
	Number of Workers					
Illinois*						
Industrial electric heaters, sensors & controllers manufacturing & assembly	44	42	0	0	42	95
Utah*						
Meat processing	23	22	1	0	22	96
Airbag manufacturing	108	104	1	0	104	96
Undergarment sewing	100	92	6	0	92	92
Cabinetry manufacturing	4	4	0	0	4	100
Door manufacturing	16	16	0	1	15	94
Aluminum parts manufacturing	30	25	0	2	26	87
Chemical testing laboratory	69	64	0	2	63	90
Distribution center	8	8	0	0	8	100
Office work	28	28	0	0	28	100

* Not included in analyses reported in this report

2.2.3. Initial Classifications of Jobs into Low, Medium and High Exposure Categories:

Jobs were initially classified into low, medium and high job physical exposures based on an initial walkthrough visit by the Job Physical Exposure Assessment Team members. Variables that were particularly used to initially classify jobs into their three categories for purposes of enrollments were: hand/wrist force (≤2, 3-4 and ≥5 on Borg CR-10 scale), exertions/min. (≤4, 5-8, >8), % duration of exertion (≤20%, 21-40%, >40%) and hand/wrist posture (Good, Fair, Poor). In most cases, a combination of these four variables was used to classify jobs into low, medium and high risk (Appendix A). The primary purpose of these initial classifications was to attempt to ensure that approximately one-third of subjects would be in the low, medium and high job physical exposures for purposes of assuring power to detect health effects across a spectrum of job physical exposures. The initial job classification scheme was otherwise not utilized in this study.

2.3. Inter-Rater Reliability:

2.3.1. Health Outcome Assessment:

The performance of the standardized physical examination was recorded on a CD and copies of the CD were distributed to all Health Outcomes Assessment Team members. One principal investigator responsible for all health outcome data worked in sessions with the health teams in Utah and Wisconsin where the procedures were demonstrated, practiced, and finalized. In addition the same principal investigator participated in early enrollment sessions both in Utah and Wisconsin to ensure that the physical examination procedures were uniform and consistently applied by the Health Outcomes teams at both research centers.

2.3.2. Job Physical exposure Assessment:

Members of the Job Physical Exposure Team met several times to precisely define, clarify, and discuss each exposure variable and its method of measurement. Variable definitions and methods were assembled into a written document. Each member of the Job Physical Exposure Assessment Team collected data according to these standardized methods.

Prior to extracting the videotaped data, the principal investigator responsible for job physical exposure assessments worked closely with the job physical exposure analysts in Utah and Wisconsin to ensure standardization of these data measurements and analyses. Each member of the Job Physical Exposure Assessment Team reviewed a 15 second video once every two weeks for 6 months. Rater differences were discussed, and resolved with teleconferencing and visit(s) to Utah by one principal investigator. All job physical exposure analysts individually analyzed twenty-five new tasks for standardization of job physical exposure variables. Analysts' intraclass correlation coefficients were 0.69 for peak force/intensity, 0.61 for average force/intensity, 0.92 for numbers of exertions, and 0.93 for total duration of exertion. These results compared favorably with other reported results, including those of Latko for ratings of repetition $r^2 = 0.53$ and numbers of exertion per cycle $r^2 = 0.58$ (Latko 1997). For posture, we assessed percentage agreements between the Strain Index categories among analysts. They ranged from 56-87% between any 2 raters, and average 69%. Thus, there was reproducibility of ergonomic analyses

2.4. Health Outcomes Methods:

2.4.1. Baseline Health Outcomes Assessment:

At baseline, participating workers completed a questionnaire, structured interview and a medical examination. All workers were given bilateral nerve conduction studies. The data collection forms are in Appendix B.

2.4.1.1. Baseline Health Outcomes Questionnaire:

The baseline health outcomes questionnaire (Appendix B1) was self-administered using a laptop computer. A member of the health team was present to assist with any problems or clarifications the participating workers needed while completing the questionnaire. Some workers' questionnaires were administered by a research team member if the worker did not want to enter data or had other difficulty with use of computers. Administration of the questionnaire typically required 20 minutes.

The questionnaire (Appendix B1) included personal information about age, gender, height, current body weight, maximum weight ever and weight at age 20, marital status, ethnicity, highest completed education level, hand preference, and types and durations of hobbies and physical exercises outside of work. Employment-related questions included company name, department, current job title and duration of time on current job (months, years).

Workers were also asked about the presence of a variety of self-reported medical conditions (told by a physician): diabetes mellitus, thyroid, inflammatory arthritis (rheumatoid, lupus, etc.), degenerative or osteo-arthritis and body part affected, gout, alcoholism, kidney failure, high cholesterol, and high blood pressure. They were asked about tobacco consumption, alcohol consumption, and consumption of caffeinated coffee and beverages. In addition, workers were asked if their blood relatives were ever diagnosed with CTS. Women were additionally asked if they were currently pregnant; using birth control pills, post menopausal and/or receiving estrogen replacement.

The questionnaire also had a variety of psychosocial questions. These included: (i) family problems, (ii) feeling of depression, (iii) job satisfaction, (iv) worker's general health compared to others, (v) physically exhausted, (vi) mentally exhausted (vii) getting along with co-workers (viii) supervisor appreciation of work, (ix) employer cares about worker's health and safety (x) take this job again and (xi) recommend his/her job to someone else.

2.4.1.2. Baseline Health Outcomes Structured Interview:

A member of the research team (board certified occupational medicine physician, occupational medicine resident, physical or occupational therapist) conducted the structured interview (Appendix C2). The interviewer posed questions to the participant and recorded responses on a laptop computer. One section of structured interview emphasized the history of a variety of musculoskeletal conditions and injuries. These included previous diagnoses by a healthcare professional of (i) thoracic outlet syndrome, (ii) rotator cuff tear, (iii) lateral epicondylitis, (iv) medial epicondylitis, (v) cubital tunnel syndrome, (vi) DeQuervain's, (vii) hand/wrist/forearm fracture, (viii) hand/wrist tendonitis, (ix) CTS, (x) Raynaud's disease and trigger finger. Workers were asked to indicate whether a specific disorder was on their right side, left side or bilateral and the year of diagnosis. They were asked if they *ever* had snapping or locking of a specific finger, fracture of a specific bone, dislocated a specific body joint, pinched nerve in back or neck, had surgery and were they ever hospitalized for reasons other than for surgery or childbirth.

There were more detailed histories of pain, ache, stiffness, numbness or tingling in each body part using a body diagram (Appendix B3). These included current pain, pain in the last one-month, location of pain, intensity of pain, and duration of pain. A body diagram was used to specify the location of pain and a pain scale was used to quantify the intensity of pain (Appendix B7). Regarding numbness/tingling symptoms, questions included current numbness/tingling, numbness/tingling in the last one-month, and duration of numbness/tingling. Additionally, for those workers with numbness/tingling in the hand/wrist/fingers they were asked all together the duration of numbness and tingling, and whether their symptoms (i) became worse at night, (ii) were present on awakening, (iii) became worse when holding an object, and/or (iv) were intermittent or continuous when they presented. A hand symptoms diagram (palmer and dorsal for left and right sides) was used to specify the location of pain and numbness /tingling using different symbols (Appendix B4).

2.4.1.3. Baseline Anthropometric Measurement, Heart rate and Blood Pressure:

A few anthropometric variables and heart rate and blood pressure were measured during the baseline data collection process. These measurements included: (i) resting heart rate, (ii) blood pressure, (iii) height and weight, and (iv) wrist depth and width.

2.4.1.4. Baseline Health Outcomes-Physical Examinations:

The primary (first) physical examination of the worker was performed by a occupational therapist, physical therapist, occupational medicine resident or physician who was a member of the health outcomes data collection team. The medical examination focused on the presence or absence of physical signs and provocative maneuvers related to the neck, shoulder, elbow, wrist, and fingers (Appendix B5). Some of these included:

- Neck: Spurlings sign, pain in upper middle trapezius, levator and rhomboid and cervical range of motion.
- Shoulder: painful arc, shoulder abduction range of motion < 160°, impingement sign (Neer), empty can test for supraspinatus tendonitis, external rotator weakness and resisted elbow flexion test (biciptal tendonitis) for shoulder.
- Elbow: evaluation of six different tender points at lateral epicondyle and radial head, tenderness at medial epicondyle and 1 cm distal to medial epicondyle, resisted wrist/phalangeal extension, resisted middle finger extension, resisted wrist/phalangeal flexion, resisted middle finger flexion, Tinel's retrocondylar groove, and Tinel's cubital tunnel.
- Wrist: FCR, FCU, flexor tendon, 1st compartment, other extensor compartment and ECU tenderness, resisted wrist flexion with apin at FCR and FCU, resisted phalangeal flexion, Finkelstein's, resisted phalangeal extension for in other extensor compartments, resisted extension for pain in ECU, Phalen's 60 s test, and Tinel's proximal, mid and distal carpal tunnel tests.
- Fingers: A1 tenderness for each digit (1 to 5), tendon nodule for each digit (1 to 5), locking/triggering for each digit (1 to 5), CMC deformity and CMC grind test.
- Tender points were evaluated using an applied force of 4 kg. Left and right sides were evaluated separately. Observational data were collected regarding signs of rheumatoid arthritis, Heberden's and Bouchard's nodes, dorsal and volar wrist ganglia and Dupuytren's contracture.

A board-certified occupational medicine physician performed a second standardized examination of the positive findings from the first examination and evaluated findings that might be positive based on the structured interview (i.e., pertinent negative examination findings). The physician also provided diagnostic impression(s).

2.4.1.5. Nerve Conduction Study

Nerve Conduction Studies (NCS) were performed by Board Certified Physiatrists on every subject enrolled in the study. All workers received an NCS at baseline as well as at the study conclusion (provided they were still enrolled at that time). Workers who had normal baseline

NCS but reported new CTS symptoms on two consecutive monthly follow-up health assessments had repeat NCS done.

NCS testing protocol included bilateral paired transcarpal, bilateral antidromic median digital sensory, bilateral median thenar motor, bilateral antidromic ulnar digital sensory and bilateral ulnar hypothenar motor studies (Appendix B6). The transcarpal responses were recorded at the wrist with a 3cm bar electrode with stimulation in the palm with an 8cm distance between the cathode and E1 electrode. The median digital sensory studies were recorded from the long finger at 12 cm with ring electrodes with a 4cm interelectrode distance. The ulnar digital sensory studies were recorded from the little finger at 11 cm with ring electrodes. The median motor studies were done at 6cm with the E1 electrode over the thenar midpoint of abductor pollicis muscle and E2 on the dorsal distal phalanx of the thumb. The ulnar motor studies were done at 6cm with the E1 electrode over the hypothenar midpoint of abductor digiti minimi muscle and E2 on the dorsal distal phalanx of the little finger. All studies included latencies, amplitudes, and stimulus parameters. All studies were done on a TECA Synergy EMG machine with hand dorsum skin temperature measured with a portable surface thermistor. A minimal temperature of 30ºC was assured before the nerve conduction studies were done.

NCS data were classified for each hand of each subject into categories of 'normal' and 'abnormal' as well as classified by the severity of median mononeuropathy at the wrist into 'mild' or 'moderate/severe' (Table 2.2). Those workers showing signs of a systemic neuropathy (e.g., diabetic polyneuropathy) were excluded from these analyses. Remaining workers were classified as normal or abnormal (abnormal further categorized, as mild or moderate/severe) based on the criteria in Table 2.2 below.

Table 2.2: Parameters for NCS test result classification

Classification		Transcarpal Delta*	Sensory Latency	Motor Latency
	Normal	≤ 0.55 ms	≤ 3.85 ms	≤ 4.45 ms
Abnormal	Mild	> 0.55 ms	≤ 3.85 ms	≤ 4.45 ms
	Moderate	> 0.55 ms	> 3.85 ms	≤ 4.45 ms
	Severe	> 0.55 ms *or absent*	> 3.85 ms	> 4.45 ms

* Transcarpal Delta = median nerve latency – ulnar nerve latency

Most workers were classified based solely on the criteria of Table 2.2. However, some workers had to be individually reviewed by a Board Certified Physiatrist for proper classifications. These workers fell into two groups, (i) those missing transcarpal unlar latency and (ii) those whose pattern of abnormality/severity for transcarpal delta, sensory latency, and motor latency showed an atypical pattern. If an ulnar transcarpal latency was not obtained (not done bilaterally initially as it can be technically difficult), absolute median transcarpal latency was used in conjunction with median nerve digital sensory and motor latencies to determine appropriate classification. A very small number of workers presented atypical latencies that did not conform to the test limits in Table 2.2. For example, a worker had normal transcarpal delta and normal sensory latency but abnormal motor latency. In these atypical situations the physiatrist would consider both amplitudes and latencies, compare these with data for the opposite hand, and consider data from NCVs for that worker performed at different times during the study to determine normal versus abnormal NCV classification as well as the severity of abnormality.

An "abnormal NCV test" was one where the physiatrist marked the test results as mild or moderate/ severe mononeuropathy at the wrist.

2.4.1.6. Monthly Follow-up Health Outcomes Interview:

After completing the baseline health outcomes evaluations, workers were placed into a monthly follow-up system. Each month, a member of the health outcomes assessment team would visit each of the facilities, and conduct a brief interview with each of the participating workers. These interviews typically lasted for less than five minutes and were conducted at the worker's workstation. All interviews were conducted using laptop computers to enable referencing of the health status from the previous month. To be eligible to be included in the analyses for this report, a worker *must* have undergone baseline evaluation, *and* at least one monthly follow-up cycle.

The monthly follow-up interview began by referencing the worker's health data from the last follow-up (baseline data for first follow-up). If the workers had pain and/or numbness and tingling during the last follow-up, they were asked if the pain and/or numbness and tingling had changed or resolved. If the worker's pain and/or numbness and tingling had resolved since the last follow-up, the workers was asked how many days ago did the pain and/or numbness/tingling go away. If the pain and/or numbness/tingling did not go away, the workers were asked to provide pain rating and percent of days they had pain and/or numbness/tingling since last follow-up. A pain scale was used to determine pain intensity (0 = no pain at all, 10 = worst possible pain.

2.4.1.7. New Pain and/or Numbness/Tingling Episode:

The workers were next asked if they had developed any new pain in neck, shoulder, elbow, forearm, wrist or digits since the last follow-up. They were asked if they had developed any new numbness/tingling either in forearm, wrist or digits. If new pain was identified, workers were asked when did the pain start (days ago), what percentage of time they experienced the pain, to rate the intensity of pain on the pain scale, and what they believed was the cause of the pain. When asked to provide their opinion about what caused the new pain and/or numbness tingling, the following options were used: (i) unsure, (ii) accident outside of work (slip/trip/fall, motor vehicle accident, etc…), (iii) something outside of work (not an accident), (iv) accident at work (slip/trip/fall, motor vehicle accident, etc…), or (v) something at work (not an accident). For the purpose of this report workers impression of work-relatedness was not considered in determining new episodes of pain and/or numbness/tingling. New episodes were classified as caused by an accident or not caused by an accident.

The therapist then performed a physical examination of the affected body region including hand pain diagram if needed. This examination was performed using the protocol for baseline physical examination of the affected body region. If new numbness/tingling was indicated in the forearm, wrist or the digits workers were asked when did the numbness/tingling start (days ago), what percentage of time they experienced numbness/tingling at night, in morning and during day, whether the numbness/tingling was continuous, whether it was worse when holding an object, and what they believed was the cause of the numbness/tingling. If new numbness/tingling was indicated in any of the median nerve served digits (digits 1-4), the worker was scheduled to undergo a semi-annual nerve conduction study, most often within the next six months. Episodes of pain and/or numbness/tingling were monitored monthly until they resolved during which time changes in percentages of time and/or ratings of pain were recorded. During an episode, an increase in pain rating and/or an increase in percentage of time experienced pain triggered additional physical examinations.

2.4.1.8. Miscellaneous Monthly Interview Questions:

A series of questions were included in the monthly interview. These questions were asked semiannually. These included: (i) current weight, (ii) diabetes, (iii) high blood pressure and (iv) high cholesterol. Female workers were asked if they were currently pregnant.

2.4.1.9. Recording of Job Changes:

Workers were asked to describe any job changes they had since the previous monthly interview. The objective was to assist the Job Physical Exposure teams to determine if additional follow-up of job (more frequent than quarterly) was required. Job change questions included (i) moving to a new job/line, (ii) using new equipment/tools, (iii) an increase or decrease in production rate, (iv) a change in work hours ($\geq$ 5 hours per week), and (v) any “other” changes. Workers were also asked when these changes occurred.

2.4.1.10. Quarterly Interview and Physical Examination by Physician:

Every three months, a physician accompanied the therapist to perform a second follow-up interview and physical examination. The second quarterly interview and physical examination by a physician were identical to those performed by a therapist. In this way, the health outcomes data were checked for consistency, and a physician’s diagnostic impression was provided four times per year for each employee.

2.4.1.11. Exit Interview:

Wherever possible, workers in Utah and Wisconsin were given an exit questionnaire, structured interview, physical examination and NCS.

2.5. DUE Musculoskeletal (MSD) Symptoms and Disorders Case Definitions:

Many workers experienced more than one episode of DUE disorders during the observation period (“*recurrent CTS”*, “*recurrent lateral epicondylitis”, etc.* characterized by the number of episodes). While recurrences were tracked in this study, this report considers only the conservative analysis of time to first event. It does not incorporate cumulative incidence measures. The most conservative analysis is time to first lifetime event. Therefore, workers who had a prior specific DUE disorder (for example, CTS for CTS analysis) or current DUE specific disorder at baseline (for example, CTS for CTS analysis) were excluded from the cohort. The following description relates to CTS. DUE symptoms and other DUE MSDs case definitions are summarized in Table 2.3.

Incident CTS case status was determined bilaterally for each worker. An incident CTS case included CTS symptoms plus abnormal NCS consistent with median mononeuropathy at the wrist within 6 months of symptoms. Workers were considered symptomatic for CTS if they unilaterally (or bilaterally, depending upon the type of analysis, see below) presented symptoms of numbness and tingling in two or more median nerve served digits for two or more consecutive monthly follow-up periods. Those workers showing signs of a systemic neuropathy (e.g., diabetic polyneuropathy) were ineligible to become a case. Remaining workers were classified as normal or abnormal (abnormal further categorized, as mild or moderate/severe) based on the criteria discussed in Table 2.2.

All workers with symptoms of numbness or tingling were eligible to become a CTS case except those whose symptoms were caused by an accident. Workers were asked whether their new numbness/tingling was caused by an accident at work or outside of work (slip/trip/fall, etc)? Those workers who responded that an accident inside or outside of work (slip/trip/fall, etc) caused their numbness/tingling were included in the study but were right censored as a non-event at the time of the accident.

Case definitions for CTS and other DUE disorders are summarized in Table 2.3. For each DUE disorder there are three different potential analyses. The following explanation is provided for CTS:

Dominant Hand Analysis: Job physical exposure for a worker's dominant hand is compared with the CTS status (case or non-case) for the dominant hand. Non-dominant hand job physical exposure and CTS status are ignored.

Person Analysis: Job physical exposure is the higher of exposures from left and right hands of the worker. Time to event is whichever hand first meets the case definition of CTS. For example, using the Strain Index (SI) as the job physical exposure method if the worker has an SI score of 7.5 for the right hand, and 12.0 for the left hand, a score of 12.0 is assigned as the job physical exposure. If the worker develops CTS in *either* hand (or both hands simultaneously) during the course of the study then he/she becomes an incident case for CTS provided the worker is otherwise eligible to become a CTS case. Regardless of which hand develops CTS first (or neither hand if the worker does not become a case), the job physical exposure level will be defined as SI = 12.

Hand Specific Analysis (2n Analysis): For this analysis, the job physical exposure for worker's left hand is compared to the CTS status for the worker's left hand, and job physical exposure for the right hand is compared to the CTS status for right hand. Because both hands may separately develop CTS and are assumed to have independent job physical exposure, this method has the effect of doubling sample size (n). However, because both arms are associated with the same person, cluster analysis was used.

Table 2.3: DUE Disorders Case Definitions

Disease criteria for case	Exclusions & Right Censor Conditions
Carpal Tunnel Syndrome: Case if true: (1+2+3) OR 4 1. Numbness/Tingling (N/T) in 2 or more median nerve served digits (1-4) for at least 2 consecutive monthly follow-up interviews plus abnormal nerve conduction study (NCS) consistent with median mononeuropathy at the wrist that was independently interpreted by a blinded, board certified physical medicine and rehabilitation physician. 2. Individual reports cause as not an accident during monthly follow-up interview. 3. Time difference between +NCS and consecutive N/T follow ups ≤ 6-months 4. Surgery/injection for CTS provided the surgery/injection cause was not an accident.	**Exclusions:** • Met the case definition at baseline • Evidence of systemic neuropathy (determined by board certified physical medicine and rehabilitation physician.) • Prior carpal tunnel release surgery • Prior diagnosis of CTS by a Physician • Prior injection for CTS • Amputation of second or third digit at MCP or PIP in either hand **Right Censor as non event:** • Develops CTS symptoms from an accident
Lateral Epicondylitis: Case if true: (1+2+3) OR 4 1) Lateral elbow pain for ≥ 50% days on monthly follow-up interview. 2) Pain upon palpation of 1 or more of 6 lateral tender points (from monthly follow-up physical exam). 3) Individual reports cause as not an accident during monthly follow-up interview. 4) Surgery or injection for lateral epi, provided the surgery/injection cause was not an accident.	**Exclusions:** • Met the case definition at baseline • Prior lateral elbow surgery • Prior elbow surgery of unknown type • Prior diagnosis of lateral epi • Prior treatment for lateral epi • Prior radial nerve pain **Right Censor as non event:** • Develops lateral epi. symptoms from an accident • An elbow injury (i.e. accident, fall, etc..)
Medial Epicondylitis: Case if true: (1+2+3) OR 4 1) Medial elbow pain for ≥ 50% days on monthly follow-up interview. 2) Pain upon palpation of 1 or more of 2 medial tender points (from monthly follow- up physical exam). 3) Individual reports cause as not an accident during monthly follow-up interview. 4) Surgery or injection for lateral epi, provided the surgery/injection cause was not an accident.	**Exclusions:** • Met the case definition at baseline • Prior medial elbow surgery • Prior elbow surgery of unknown type • Prior ulnar neuropathy or cubital tunnel surgery, OR *clinical impression* of ulnar neuropathy. • Prior diagnosis of medial epi • Prior treatment of medial epi **Right Censor as non event:** • Develops medial epi symptoms from an accident • An elbow injury (i.e. accident, fall, etc..)

Table 2.3 continued: DUE Disorders Case Definitions

Disease criteria for case	Exclusions & Right Censor Conditions
deQuervain's: Case if true: (1+2+3+4) OR 5 1. Radial wrist pain for ≥ 50% days on monthly follow-up interview. 2. 1st extensor compartment tenderness from monthly follow up physical exam. 3. Positive Finkelstein test (active) from monthly follow up physical exam. 4. Individual reports cause as not an accident during monthly follow-up interview. 5. Surgery or injection for deQuervain's, provided the surgery/injection cause was not an accident.	**Exclusions:** • Met the case definition at baseline • Prior deQuervain's surgery • Prior deQuervain's treatment (injection) • Prior deQuervain's diagnosis • History of CMC/Wrist/MCP arthritis **Right Censor as non event:** • Develops deQuervain's symptoms from an accident • Suffers a wrist injury (i.e. accident, fall, etc..) • Develops CMC/Wrist/MCP arthritis
Extensor Tendinitis (compartments 2-6) Case if true: (1+2 and/or 3+4) OR 5 1. Dorsal wrist pain for ≥ 50% days on monthly follow-up interview. 2. 2-6 extensor compartment tenderness. 3. Positive resisted wrist extension 4. Individual reports cause as not an accident during monthly follow-up interview. 5. Surgery or injection for extensor tendonitis, provided the surgery/injection cause was not an accident.	**Exclusions:** • Met the case definition at baseline • Prior wrist extensor tendinitis surgery • Prior wrist extensor tendinitis treatment (injection) • History of wrist arthritis **Right Censor as non event:** Develops wrist extensor tendinitis symptoms from an accident • suffers a wrist injury (i.e. accident, fall, etc..) • Ddevelops wrist arthritis
Wrist Flexor Tendinitis Case if true: (1+2+3+4) OR 5 1. Volar wrist pain – from Hand Pain Diagram 2. Digital flexor tendon tenderness from monthly follow up physical exam. 3. No numbness/tingling in digits 1-4 from monthly follow up interview. 4. Individual reports cause as not an accident during monthly follow-up interview. 5. Surgery or injection for digital flexor tendinitis, provided the surgery/injection cause was not an accident.	**Exclusions:** • Met the case definition at baseline • Prior flexor tendinitis surgery • Prior flexor tendinitis treatment (injection) • History of wrist arthritis **Right Censor as non event:** Develops flexor tendinitis symptoms from an accident • Suffers a wrist injury (i.e. accident, fall, etc..) • Develops wrist arthritis
Trigger Finger / Trigger Thumb Case if true: (1+3) OR (2+3) OR 4 1. Pain in the finger from monthly follow-up interview and Focal tenderness over A-1 pulley from physical exam 2. Demonstrated triggering from monthly follow-up physical exam OR monthly interview. 3. Individual reports cause as not an accident during monthly follow-up interview. 4. Surgery or injection for trigger finger, provided the surgery/injection cause was	**Exclusions:** • Met the case definition at baseline • History of trigger finger/thumb • Prior finger/hand surgery • Prior treatment for trigger finger/thumb (injection) • MCP/finger OA at baseline **Right Censor as non event:** Develops trigger finger/thumb from an accident • Suffers a hand/finger injury (i.e. accident,

not an accident..	fall, etc..)

Table 2.3 continued: DUE Disorders Case Definitions

Disease criteria for case	**Exclusions & Right Censor Conditions**
Non-Specific Pain Case if true: (1+2) 1) Pain in DUE with intensity ≥ 6 for ≥ 50% of days that is NOT associated with a specific disorder. 2) Individual reports cause as not an accident during monthly follow-up interview.	**Exclusions:** • Met the case definition for non-specific pain at baseline • Met the case definition for any specific disorders at baseline a. Carpal Tunnel Syndrome b. Lateral Epicondylitis c. Medial Epicondylitis d. deQuervain's e. Extensor Tendinitis f. Digital Flexor Tendinitis g. Trigger Finger / Trigger Thumb **Right Censor as non event:** • Becomes an incident case for ANY specific disorder a. Carpal Tunnel Syndrome b. Lateral Epicondylitis c. Medial Epicondylitis d. deQuervain's e. Extensor Tendinitis f. Digital Flexor Tendinitis g. Trigger Finger / Trigger Thumb • Suffers a DUE injury (i.e. accident, fall, etc..)
Symptoms Case if true: (1+3) OR (2+3) 3) Pain in DUE with intensity ≥ 6 for ≥ 50% of days 4) Pain in DUE of any intensity AND taking medication for pain. 5) Individual reports cause as not an accident during monthly follow-up interview.	**Exclusions:** • Met the case definition for non-specific pain at baseline **Right Censor as non event:** • Suffers a DUE injury (i.e. accident, fall, etc..)
Any Disorders Case if true: (1+2) ii. Meets any of the following case definitions as defined above: a. Carpal Tunnel Syndrome b. Lateral Epicondylitis c. Medial Epicondylitis d. deQuervain's e. Extensor Tendinitis f. Digital Flexor Tendinitis g. Trigger Finger / Trigger Thumb 6) Individual reports cause as not an accident during monthly follow-up interview.	**Exclusions:** • No prior history of DUE disorders including CTS at baseline (Ineligible if had any of the 7 specific disorders listed on the left. • **Right Censor if:** Develops symptoms for any disorder from an accident. • Suffers a hand/wrist/elbow injury (i.e. accident, fall, etc..).

2.6. Job Physical Exposure:

2.6.1. Baseline Job Physical Exposure Data

All job physical exposure data were collected at the facilities of the participating companies. Both quantitative and subjective measurements were recorded. All jobs performed by participating workers were recorded on digital videotape using hand-held video cameras. Each job performed by the worker was recorded for a minimum of 10 cycles or at least 20 minutes, whichever was lower. For those few jobs with cycle times longer than 20 minutes, at least one complete job cycle was recorded.

Data collection began with the analyst introducing himself/herself to the worker. The analyst then observed the job for several cycles, videotaped the job, interviewed the worker to collect relevant information about worker and jobs, obtained worker Borg CR-10 ratings, provided analyst Borg CR-10 ratings and took job physical exposure measurements (for example, weights, pushing/pulling forces, grip and pinch strengths and matching forces, etc.). To ensure the video captured an accurate representation of frequencies of different exertions, all video was recorded in "real time," without the worker being interrupted by the analysts.

Whenever new employees were recruited into the study, they underwent baseline job physical exposure data collection. Baseline data collection was performed within two months of the worker having their baseline health data assessment. Baseline data collection was broken into two major components: (i) position specific data collection and (ii) job specific data collection (Appendix C). In this study, *position* refers to the worker's overall activities in a day. *Job* refers to specific, but unique, activities performed by the worker for a certain number of hours in a given day. A position can be comprised of a single job or multiple jobs (e.g. job rotation). Job rotation was fairly common in this study.

2.6.1.1. Position Specific Job Physical Exposure Data-Field measurements:

Position specific data were collected to determine all different activities performed by the worker and related information (Appendix C). Position data included: (i) department and worker title, (ii) shift starting and ending time, (iii) different jobs performed, (iv) hours worked on each job, (v) job pace (self, line or piece rate), (iv) days worked per week, (v) prior work experience (# of years and Borg rating for DUE), (vi) having a second job (# of years, hours/week, and dominant hand Borg rating), (vii) Borg CR-10 ratings for applying a standardized 10-kg grip force, (viii) the worker's maximum grip, lateral pinch and 3-point pinch strengths, and (ix) overall Borg ratings for distal upper extremity at the beginning and end of shift.

Shift starting time, ending time, and days per week were recorded by interviewing the worker on the production floor. Next, workers were asked to briefly describe each of the jobs they performed as a part of their position held with the company. For those workers who worked multiple jobs, each job and the total consecutive hours worked on the job were recorded.

Workers were then asked to list their previous positions held, the length of time, in years, that the position was held and to provide a corresponding Borg CR-10 rating for DUE for each of the jobs listed. The first position listed was the "Current" position the employee held. Previous positions were listed until the total previous employment duration summed to 10 years, or 5 previous (6 total, including the current) positions were recorded, whichever occurred first.

Secondary employment, or second positions held outside the facility were recorded next. If the worker held a second position, a brief description of the type of work was recorded. The worker was then asked how long they had held the second position, how many hours per week they had worked at the second position, and to provide an overall Borg CR-10 rating for the dominant hand corresponding to the second position.

Workers' dominant hand grip, lateral pinch and 3-point pinch strengths were measured using grip and pinch dynamometers (3 trials for each measurement) (Appendix C). These strengths were measured with wrist in functional neutral position, upper arm hanging to the side and the lower arm horizontal and in neutral position (no forearm rotation). For grip strength measurements grip span was set at Jamar dynamometer setting 2.

Lastly, with regard to their primary position, the worker was asked to provide Borg CR-10 ratings for the level of physical stresses they felt on their distal upper extremity at the beginning of their work shift (about 30 minutes after they started their typical work day) and at the end of their work shift (about 30 minutes before the end of their typical work day). This information was gathered to estimate the accumulation of fatigue as a result of performing their various job activities.

2.6.1.2. Job Specific Job Physical Exposure Data-Field Measurements:

Data were collected for each job performed by a worker using Job Specific Data forms (Appendix C). General observations included: (i) use of gloves (type of gloves and fit), (ii) room temperature, (iii) hand contact with a hot or cold object, and (iv) localized mechanical compression (body part and intensity). Specific information included (i) measured cycle time, (ii) analyst's estimates of applied hand force for each hand and for each major task performed (Borg CR-10 ratings) (iii) weight of the workpiece or hand tool and center-of-mass offset of handtool (iv) matching grip, pinch and thrust forces for left and right hand (peak and typical values), (v) worker ratings of applied hand/wrist forces for each hand (typical and peak values, Borg CR-10 scale) and (v) analyst ratings of applied hand/wrist forces for each hand (typical and peak values, Borg CR-10 scale).

Analysts provided their ratings first to avoid biasing their ratings based on the worker's ratings. Similarly, workers were not allowed to see the analyst's ratings. For the peak task, the Borg CR-10 rating was a representation of the force required to perform the most difficult task of the job. Workers were asked to identify the most stressful task they performed with regard to the distal upper extremity. Once identified, both the analyst and the worker provided their peak distal upper extremity force ratings for that task on the Borg CR-10 scale. Analyst and worker were also asked to provide "typical" force ratings for the job for each hand (Borg CR-10 scale). In those situations where applied hand force varied during a cycle, both the analyst and the worker were asked to ignore the peak force exertions when assigning typical force rating. If the analyst or the worker felt that there was no appreciable variation in applied hand force then the typical and peak force ratings were the same.

Cycle time was determined using a stopwatch. Object weights were measured using digital platform scale and pushing and pulling forces using a force gauge (model # CSD250, manufactured by Chattilon).

Scales on grip and pinch dynamometers were covered prior to measuring matching grip and pinch forces. Workers were asked to hold the grip/pinch dynamometer exactly in the same posture as that required when using the hand-tool. Then, the worker was asked to apply a force on the dynamometer equal to the force required to grip/pinch the hand-tool. Matching thrust forces were measured using a force plate. In case of a rotary hand tool (such as a nut runner or a screw driver) a thrust bearing was used between the tool and the force plate.

2.6.2. Follow-up Job Physical Exposure Data Collection:

Every three months, a member of the job physical exposure team visited each employee. The job team had a computerized position form with them that showed the analyst what jobs the worker was performing as of the last visit (3 months prior). The analyst carefully inspected all the jobs listed and determined if there were any material changes to the jobs. In most cases, the changes were minor and did not affect exposure levels. In cases where the job parameters substantially changed, or the worker moved to different jobs all together, the new/revised jobs were measured using all the job specific data forms (Appendix C2).

2.6.3. Extraction of Data from Video Analysis

Videos were analyzed frame by frame to determine intensity of force, temporal exertion requirements, hand/wrist posture, speed of work and type of grasp, etc. for each hand separately. Some of the analyses were at the task level while the others were at the job level. Each job was divided into tasks. Our definition of a task was a unique combination of hand/wrist force, hand/wrist posture and number of exertions/cycle. During the analysis of videotape if there was a change in either hand/wrist force, hand/wrist posture or number of exertions/cycle a new task was created. Thus a job consisted of multiple tasks, each task defined by intensity of exertion (force), number of exertions/cycle, duration per exertion, hand/wrist posture and speed of exertion. Duration of task per day was the same as the duration of job per day (Appendix C). All these variables were determined by analysts. The following information was obtained from videotape analysis:

- (i) Cycle time (minutes).
- (ii) Exposure to hand/arm vibration (% of cycle time spent in negligible, visible and severe hand/arm vibration).
- (iii) Hand contact with hot/cold objects ((temperature and % of cycle time spent in contact with cold or hot objects).
- (iv) Exposure to localized mechanical compression (body part; negligible, moderate and severe localized mechanical compression; % of cycle time sent in each category).
- (v) Exposure to tool kicks (negligible, moderate, severe; % of cycle time sent in each category)
- (vi) Use of hand as a hammer (negligible, moderate, severe; % of cycle time sent in each category).
- (vii) Intensity of exertion (force) for each task using Borg CR-10 scale.
- (viii) Overall rating of force using the Strain Index methodology (Moore and Garg 1995). Each job was assigned an “overall” expert rating for force affecting distal upper extremity using the Borg CR-10 scale. Expert analyst reviewed the videotape, integrated different force exertions into a single force rating using his

judgment. The expert analyst had observed all jobs in the field and accounted for peak and typical ratings provided by an analyst and the worker during field measurements. These ratings were provided by two raters, one in Wisconsin and one in Utah.

(ix) Speed of work for each job using the Strain Index methodology (Moore and Garg 1995).

(x) Hand activity level (HAL) rating for each job using a verbal anchor scale (Latko 1997).

(xi) Number of efforts per minute at each force level using the SI methodology (Moore and Garg 1995). An effort was defined as involvement of hand prehension, regardless of the level of applied force (Moore and Garg 1995).

(xii) Total efforts/minute for each job (Moore and Garg 1995).

(xiii) Duration per exertion (seconds/exertion) for at each force level.

(xiv) Percent duration of exertion per cycle for each job using the Strain Index methodology (Moore and Garg 1995).

(xv) Hand/wrist posture for each task using the Strain Index methodology (Moore and Garg 1995).

(xvi) Overall, hand/wrist posture for each job using the Strain Index methodology (Moore and Garg 1995).

(xvii) Hand/wrist posture analysis: number of exertions in each category; % of cycle time spent in low, medium and high wrist flexion, wrist extension, and ulnar deviation; % of cycle time spent low and high radial deviation; and posture categories for peak force for each job.

The following posture categories, with reference being anatomical neutral, were used:

a. Wrist flexion: <30°, 30°-50°, >50°
b. Wrist extension: <30°, 30°-50°, >50°
c. Ulnar deviation: <10°, 10°-25°, >25°
d. Radial deviation: <5°, 5°-25°.

(xviii) Forearm rotations for each job (% of cycle time spent with forearm rotation ≥ 45°)

(xix) Exertions with elbow extension <70° and >135° for each job (number of exertions; % of cycle time spent in each category; forearm position: neutral, prone, supine)

(xx) Pinching and gripping for each job (type of grasp: power, oblique, palmer grip, palmer pinch, 3-point, 2-point, lateral and 2-finger scissor; grip/pinch span; % of cycle time spent in each grasp)

In summary, all field measurements were either at the worker level or job level. All videotape analyses ere either at the job level or task level. These measurements were combined to quantify job physical exposures at the worker level, job level and task level. Table 2.4, 2.5 and 2.6 summarize the job physical exposure assessments at the worker level, job level and task level.

Table 2.4. Physical Exposure at the worker level (measurements/observations in the field)

Exposure Type	Measurements
General	Department and worker title, shift length
Pace	Self, line, piece work
Job rotation	No. of jobs, duration of each job, title of each job
Prior work experience	Title, years on each job, and worker Borg CR-10 rating for DUE and each job
Second job outside facility	Title, years on second job, and worker Borg CR-10 rating for dominant hand and second job
Strength	Grip, lateral pinch and 3-point pinch for dominant hand
Fatigue	Overall worker DUE Borg CR-10 rating for dominant hand at the end of the shift and beginning of the shift

2.6.4. Job Physical Exposure Data Analyses

All measured variables in the field and those obtained from videotape analyses were entered into a central database. The job physical exposures were calculated at task, job and worker levels (Tables 2.4 to 2.6). For each job average and peak force, overall force, total number of exertions/min, average and worst hand wrist posture, and several other variables listed in Table 2.5 were determined. Exposures at the job level were used to assign exposure at the worker level as discussed later under assigning exposure at the worker level.

2.6.4.1. Classifications of TLV for HAL and the Strain Index

A combination of the peak force rating (RPE) and HAL rating was used to determine TLV for HAL classifications (below the Action Limit (AL), between the AL and TLV, and above the TLV) using the ACGIH (2002) methodology. These are referred to as TLV for HAL categories 1, 2 and 3 respectively. Two different peak force ratings were used (worker peak force rating and analyst peak force rating) to determine TLV for HAL classification. The analyst's overall force rating (intensity of exertion converted from Borg CR-10) was used to calculate the Strain Index score (SI score). Analyst's overall RPE ratings were converted into intensity of exertion ratings for the SI calculations by matching verbal anchors from the RPE and SI intensity of exertion scales. For example, analyst overall RPE ratings from 0-2 (light), were assigned an SI intensity of exertion rating of 1 (light). For RPE ratings of 3 (moderate)-4 (somewhat hard) an SI rating of 2 (somewhat hard) was assigned and so on. TLV for HAL and SI scores were calculated for each worker and job performed throughout the follow-up period. Peak force, highest repetition and worst posture were determined from the jobs that resulted in the highest exposure for these variables (peak exposure, Figure 2.2). The cut points used for the TLV for HAL were those prescribed by the ACGIH (2002). These were (peak force/(10-HAL)) < 0.56 for below Action Limit (AL) and (peak force/(10-HAL)) > 0.78 for above Threshold Limit Value (TLV). The cut points used for the Strain Index were Strain Index score (SI score) ≤ 6.0 and >6.0 for the two category model; and SI score < 6.0, > 6.0 to ≤ 12.0, > 12.0 to ≤ 18.0, >18.0 to ≤ 24.0 and > 24.0 for the five category model.

Table 2.5. Physical Exposure at the job level (measurements/observations in the field (m) and from videotape analysis (v))

Variable	Analyst	Worker
Cycle Time (min)	• SI definition (v)	

Force	• DUE force rating (Borg CR-10)
	  ○ Peak force (m)
	  ○ Typical force (m)
	  ○ Overall force (v)
	• Object/tool weight and Center mass offset (m)
	• Pushing/pulling force (m)
		• DUE force rating (Borg CR-10)
		  ○ Peak force (m)
		  ○ Typical force (m)
		• Matching force
		  ○ Grip force (m)
		  ○ Pinch force (m)
		  ○ Thrust force (m)

Repetition	• HAL Rating (v) • No. of exertions/min (SI) (v)	
%Duration of Exertion	• % duration of exertion (v)	
Exposure/day (hours)	• Supervisor/worker (m)	

Hand/wrist Posture	• Posture categories
	  ○ Wrist flexion: <30°, 30°-50°, >50° (v)
	  ○ Wrist extension: <30°, 30°-50°, >50° v)
	  ○ Ulnar deviation: <10°, 10°-25°, >25° (v)
	  ○ Radial deviation: <5°, 5°-25° (v)
	• No. of exertions in each category (v)
	• % of cycle time in each category (v)
	• Peak force posture categories (v)
	• Overall SI posture (v)	

Elbow Posture	• Extension < 70° and > 135°
	  ○ No. of exertions (v)
	  ○ % cycle time (v)
	• Forearm position (Neutral, prone, supine) (v)	

Forearm Rotation	• % of cycle time with forearm rotation > 45° (v)	
Grip/pinch	• Type of grasp/pinch (v) • Grip/pinch span (v) • % cycle time in each type of grasp/pinch (v)	
Localized Mechanical Compression	• Body part • Category (Negligible, moderate, severe) • No. of exertions (v) • % of cycle time	
Hand as hammer	• Category (Negligible, moderate, severe) • No. of exertions (v)	
Tool kicks	• Category (Negligible, moderate, severe) • No. of exertions (v)	
Gloves	• Type and fit (m)	

Table 2.6. Physical exposure at the task level from videotape analysis.

Task Description	Force (Borg CR-10)[1]	Number of exertions/min (SI)[2]	Hand/wrist Posture (SI)[2]	Duration/exertion (seconds)	Speed (SI)[2]

[1] Borg CR-10 scale, [2] Strain Index definition

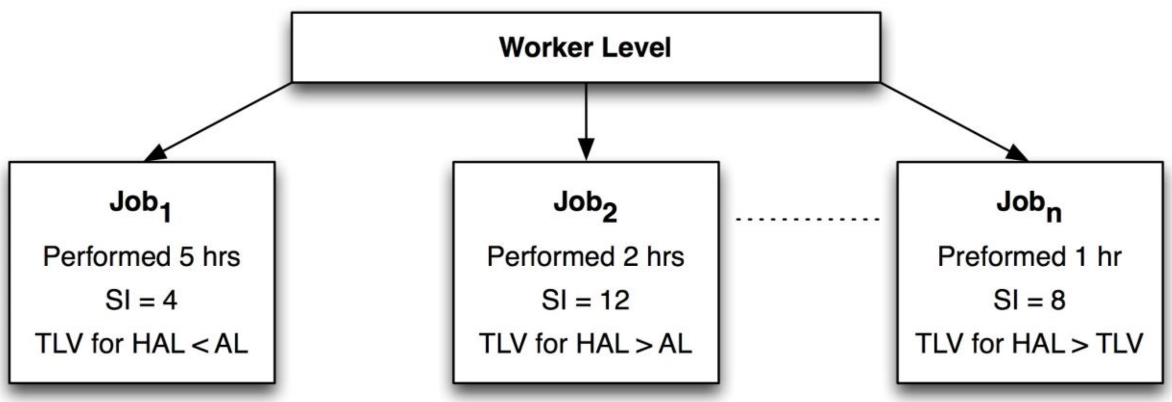

Figure 2.2: Example of a Worker's Job for Illustrating Exposure Classification.
Job 1 represents the longest job performed in the day and thus it is the typical exposure for the Strain Index (SI) and Threshold Limit Value for Hand Activity Level (TLV for HAL). Job 2 represents the peak exposure for the SI and Job n represents the peak exposure for the TLV for HAL as it has the highest threshold limit value, which exceeds the TLV.

2.6.5. Assigning Exposure at the Worker Level

Twenty percent of the workers performed more than one job during their workday or rotated jobs. As there is no consensus method to quantify job exposures for a worker who performs two or more jobs (Garg and Kapellusch 2009a), TLV for HAL and SI score were summarized in two different ways. These included "typical exposure" and "peak exposure." Typical exposure was defined as the exposure from a job the worker performs most of the time. Peak exposure was defined as exposure from a job that produces the highest job exposure measures (SI score or TLV for HAL). See Figure 2.2 for graphic representations. It should be noted that the peak SI score and peak value for TLV for HAL might be from different jobs.

2.7. Statistical Analyses:

The unit of analysis in this study is an individual worker. All analyses were performed on study cohort (subjects with complete baseline data and at least one-month follow-up data). Using baseline data, we calculated lifetime prevalence of symptoms and specific distal-upper-extremity musculoskeletal disorders (DUE MSDs) and one-month period prevalence of symptoms and DUE MSDs. Baseline prevalence of specific DUE MSDs including epicondylalgia, deQuervain's, trigger digit and hand/wrist tendinitis were aggregated into baseline prevalence of non-CTS DUE MSDs. Similarly, past history of specific DUE MSDs were aggregated into lifetime prevalence of DUE MSDs. The prevalence of DUE symptoms was calculated by dividing the number of individuals reporting symptoms by the total population of the cohort. The prevalence of a DUE MSD was calculated by dividing the number of individuals who met case definition of that disorder by the total population of cohort.

2.7.1. Incidence rates:

During longitudinal observations, there were many workers who experienced more than one episode of DUE MSDs during the observation period (e.g. recurrent CTS characterized by the number of episodes). While recurrences were tracked in this study, this report considers only the conservative analysis of time to first event during the observation period. Workers who had the specific DUE MSD prior to or at baseline were considered to be ineligible to become an incident case for that disorder (Table 2.3). Incidence rate was defined as number of new cases per 100 participants per year.

Separate analyses were performed for each DUE MSD. Each health outcome, such as incident cases of CTS, was analyzed using the proportional hazards regression model (Cox regression model). The Cox proportional hazards model (Cox 1972) was chosen as it takes advantage of more powerful person-time data that were available from this study and because this modeling does not need to quantify the underlying hazard function. The time unit of analysis was one day. Individuals who dropped out of the study contributed person-time to the analyses until the day they dropped out and were censored (Kaplan and Meier 1958). Individuals whose incident DUE MSDs were due to an acute injury (accident, slip/trip/fall) were censored one day prior to the injury. Tests of proportionality assumption were performed, and no violations of this assumption were found.

Univariate comparisons were made between a DUE MSD outcome and non-job-physical-exposure variables in order to identify relevant covariates. Potential covariates were grouped, checked for colinearity and screened for biological plausibility prior to creation of the multivariate analytic models. All potential covariates were treated as time-independent and were grouped together a priori by type (i.e., demographic, anthropometric, socioeconomic, hobbies, physical activities, psychosocial, history of other DUE disorders, and other medical history). Groups of potential covariates for these analyses are listed in Table 2.6. Relationships between the potential covariates within each category and a DUE MSD were determined using likelihood ratio test from univariate analyses. If the p-value for the likelihood ratio test was ≤ 0.10, the variable was retained for inclusion in the multivariate analysis. All relevant covariates with $p \leq 0.10$ were further evaluated to check for colinearity and biological plausibility.

Table 2.6: Potential Confounders and/or Effect Modifiers Considered for Multivariate Analyses of DUE MSDs (This example is for CTS)

Demographic	**DUE MSDs other than CTS**
Age	Baseline prevalence
Gender	Lifetime cumulative prevalence
Handedness	
Currently smoking	**Hobbies and Activities**
Ever smoked	Aerobics
Alcohol	Bicycling
Marital status	Running
Family history of CTS (blood relatives)	Swimming
Pregnancy	Walking
	Weightlifting
Anthropometric	Baseball
Body mass index	Basketball
	Football (American)
Socioeconomic	Racquetball
Education level	Snow skiing
	Tennis
Past Medical History	Water skiing
Diabetes mellitus	Gardening
Gout	Maintenance
High blood pressure	Motorcycling
High cholesterol	Piano
Rheumatoid and other Inflammatory arthritis	Remodeling
Osteoarthrosis	Snow shoveling
Kidney failure	Snowmobiling
Thyroid problem	Vibrating tools
Wrist fracture	Woodworking
Psychosocial	
General health compared to others	
Family problems	
Feelings of depression	
Feel mentally exhausted	
Feel physically exhausted	
Employer cares	
Get along with coworkers	
Job satisfaction	
Recommend job to others	
Supervisor appreciation	
Would take their job again	

Job physical exposures were treated as time varying covariates. For each multivariate model, one job physical exposure measure and all potential covariates remaining within each group after initial screening were entered simultaneously into a Cox regression model [SAS version 9.1 (TS1M3) using the TPHREG statement (SAS 2003)]. Variables were sequentially removed from the model based on the highest remaining p-value of variables in the model.

The Akaike Information Criterion (AIC) score (Akaike 1974) of the reduced model was compared to the AIC score of the full model. If the reduced model had a lower AIC score the variable was permanently removed otherwise it was retained and the variable with the next highest p-value was removed. The final model had the lowest AIC score. Separate Cox regression models were fitted for each of the job physical exposure measures (SI, TLV for HAL) as well as individual job physical exposure variables such as peak force and repetition. For each job physical exposure measure, the final multivariate model was the one that resulted in the lowest AIC score.

Job physical exposure variables were categorized to allow for assessment of non-linear relationships between exposures and survival time. The cut points used for the TLV for HAL were those prescribed by the ACGIH (2002). These were (peak force/(10-HAL)) < 0.56 for below Action Limit (AL) and (peak force/(10-HAL)) > 0.78 for above Threshold Limit Value (TLV). Cut points for those continuous variables without clearly defined prescribed limits such as the Strain Index, force, exertions per minute, and % duration of exertion, etc. were determined using a procedure adapted from Hosmer and Lemeshow's (1989) recommendations for determining cut points for a continuous covariate in a logistic regression model. A variable was divided into ten bins and hazard ratios (HRs) were calculated for each bin. Those adjacent categories with similar hazard ratios were merged together based upon biological interpretation of the variable of interest (for example, SI ≤ 6, $6 <$ SI ≤ 8 and SI > 8 would not make sense). AIC scores and the p-value for the likelihood ratio test from the reduced-categories-model were compared with those from the larger-categories-model. The procedure was repeated till either the reduced category model showed a trend (for example, SI ≤ 6.0, > 6.0 to ≤ 12.0, >12.0 to ≤ 18.0, $>18.0 \leq 24.0$ and >24.0) or only two categories were left (low exposure and high exposure). The final cut points were further adjusted to determine the cut points that resulted in the lowest AIC score, lowest p-value from the likelihood ratio test and were biologically meaningful.

2.7.2. Multiple Comparisons Concerns:

We recognized that our analyses involved examination of several indices of exposure and multiple potential risk factors, leading to a potential for chance associations due to multiple statistical tests. We were aware of formal "pure frequentist" approaches such as Bonferroni correction for significance of all tests performed. However, we believed that it was preferable and acceptable to perform a very limited number of "primary analyses" that were performed using uncorrected significance levels, given that the intended (and actual, if different) analysis plan for the study is clearly stated.

3. Cohort Descriptive Statistics

3.1. Subjects:

This study was conducted in two phases, initial study and continuation study. The continuation study began 4 years after the initial study. Workers were recruited during the first 18 months of each phase of the study. In total, baseline health assessments were performed on 1,190 workers (Figure 3.1). Baseline job physical exposure data were collected on 1,106 workers. Complete baseline data (both health and job physical exposure data) were available on 1,099 workers (Figure 3.1). Follow-up data were available on 1,065 workers who underwent at least one monthly follow up (minimum cohort follow-up time = 36 days). Those 1,065 participants were followed for a total of 3,385.7 person-years. The mean follow-up observation time was 1,161±689 days/worker (range = 36-2,355 days) and the median follow-up observation time was 987 days/worker (Figure 3.1). **The results presented in this report are on a smaller subset of data for 536 workers whose job physical exposure data has been analyzed and compiled to date.**

3.2. Baseline Descriptive Statistics:

For purposes of analyses and discussion, variables were categorized into demographic factors, social activities (physical activity including sports, hobbies), psychosocial factors, medical history and job physical factors. It should be noted that there might be complex interactions between these various variable domains that remain to be analyzed. Psychosocial factors include both occupational and non-occupational factors.

3.2.1. Demographic Data:

Demographic data from participants (n =536) are summarized in Table 3.1. The mean age of the cohort was 42.16 ± 11.55 years (range = 18.7 – 68.1). About 59% of workers were more than 40 years old and about 4% of workers were more than 60 years old at the time of enrollment (Figure 3.2). A significant majority (67.4%) of participating workers were female (mostly female workers were employed in hand intensive jobs in the participating companies). The mean weight of the participants was 80.3 ± 21.2 kg (range= 42.0-194.0 kg). A vast majority of workers (69.8%) were either overweight or obese based according to their body mass indices (BMIs) (Figure 3.3). A small minority of participants (0.6%) were underweight (Figure 3.3). The population's mean measured BMI was 29.08 ± 6.79 kg/m^2 (range =16.5-58.6). Most of the workers (85.1%) were right- handed, 9.1% were left-handed and 5.8% were ambidextrous.

About 71% of the participants were married, and most of the single participants had never been married (24%) (Table 3.1). Most workers completed either high school or higher education (86.7%). One-third of the workers (33.8%) were non-white (Table 3.1).

About 58% of the workers were either current or past smokers. A majority of workers (54.5%) regularly drank alcohol in the last year and more than 88% of those had less than 12 drinks per week.

More than one out of five workers (21.3%) had a blood relative with a diagnosis of CTS. Of the 293 female workers enrolled in the study, 2 (0.4%) were pregnant at baseline, and 20 (6.8%) became pregnant one or more times during follow-up.

A little less than one out of five workers (18.5%) had one or more job changes during the follow-up. At baseline nearly half of workers (47.0%) were subject to job rotation. Those workers performed an average of 3.4±1.6 different jobs per day (range 2-10).

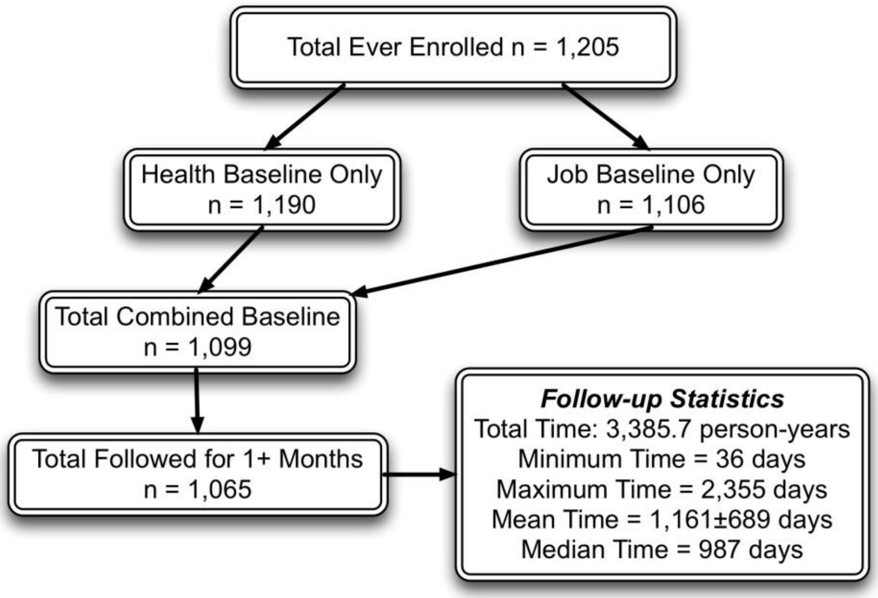

Figure 3.1: Subjects enrollment and follow-up statistics

3.2.2. Social Activities-Hobbies:

A large number of participants (85.6%) had one or more hobbies. Most of the hobbies that the workers participated in are reported in Table 3.2. The most common hobby was gardening or landscaping (52.2%), followed by using computer/internet (45.7%), knitting, sewing needlepoint, crocheting and/or arts and craft (22.2%), maintenance or mechanical work (20.5%) and remodeling tasks (20.2%). The other hobbies included using woodworking (11.1%), using vibrating tools (10.6%), riding motorcycle (10.6%), hunting and/or fishing (8.2%) and riding snowmobile (4.5%).

3.2.3. Social Activities-Physical Exercises:

A majority of workers (81.0%) participated in one or more physical exercises. Physical exercises that the workers participated in are listed in Table 3.3. The most common exercise was snow shoveling (50.2%), followed by walking (49.1%), lifting weights (16.4%), bicycling (13.3%) and running (10.2%). The other physical exercises included swimming (7.5%), aerobics (6.2%), basketball (6.0%) and baseball (4.5%). Less than 2% of the workers participated in tennis, football, water skiing, snow skiing and racquetball).

Table 3.1: Descriptive statistics for demographic variables at baseline

Variable	Category	n	Percentage or Mean ± Standard Deviation (range)
Age (years)	Continuous	536	42.2±11.55 (18.7 – 68.1)
Height (cm)	Continuous	536	165.98±9.49 (138.0-197.0)
Weight (kg)	Continuous	536	80.27±21.19 (42.0-194.0)
Most Weight in Life (kg)	Continuous	536	85.25±23.20(46.3-193.7)
Weight at Age 20 (Kg)	Continuous	536	65.95±18.44 (27.2-158.7)
BMI (kg/m^2) (measured)	Continuous	536	29.1±6.79 (16.5-58.6)
BMI (kg/m^2) (measured) *(Prescribed categories)*	Underweight (< 18.5)	3	0.6%
	Normal weight (18.5 – 24.9)	159	29.7%
	Overweight (25.0 – 29.9)	178	33.2%
	Obese Class I (30.0-34.9)	113	21.1%
	Obese Class II (35.0-39.9)	41	7.6%
	Obese Class III (≥ 40.0)	42	7.8%
Gender	Male	175	32.7%
	Female	361	67.3%
Handedness *(Dominant hand of worker)*	Right Handed	456	85.1%
	Left Handed	49	9.1%
	Both hands Equally	31	5.8%
Marital Status	Married	294	54.8%
	Never Married (Single)	129	24.1%
	Divorced	88	16.4%
	Widowed	17	3.2%
	Separated	8	1.5%
Education	8th grade or less	16	3.0%
	Some high school	55	10.3%
	High school graduate or GED	318	59.3%
	Some college	139	25.9%
	College graduate (Bachelor's degree or higher)	8	1.5%
Race	White	355	66.2%
	African American	45	8.4%
	Hispanic	64	11.9%
	Other	72	14.5%
Pregnant (n = 361) *Pregnant at baseline, Females only*	No	359	99.4%
	Yes	2	0.6%
Pregnant (n = 361) *Pregnant at any time during the follow up, Females only*	No	339	93.9%
	Yes	22	6.1%
Family History of CTS (Has anyone in your family (blood relatives only) been diagnosed with CTS?)	No	422	78.7%
	Yes	114	21.3%

Table 3.1 continued: Descriptive statistics for demographic variables at baseline

Variable	Category	n	Percentage or Mean ± Standard Deviation (range)
Job Rotation	No Yes	284 252	53.0% 47.0%
Average Number of Jobs	Continuous	252	3.4±1.6 (2-10)
Workers with Job Change	No change One or more changes	437 99	81.5% 18.5%
Second Job	No Yes		
Alcohol Consumption (Over the past year, how much alcohol do you drink in the last week?)	None 1-2 drinks/wk 3-5 drinks/wk 6-11 drinks/wk 12-17 drinks/wk 18-23 drinks/wk 24-29 drinks/wk 30 or more drinks/wk	244 134 76 48 15 10 6 3	45.5% 25.0% 14.2% 9.0% 2.8% 1.9% 1.1% 0.5%
Problem with alcohol (In the past, have you ever had a problem with alcohol?	No Yes	511 25	95.3% 4.7%
Smoking (Have you ever smoked tobacco?)	Never Yes, currently Yes, in the past	223 184 129	41.6% 34.3% 24.1%
Smoked Ever Combined current and past smoking	No Yes	223 313	41.6% 58.4%
Cups of Coffee/day (How many cups of caffeinated coffee do you drink in an average day?)	Continuous	536	1.83±3.55 (0-36.0)
12 oz. glasses of Caffeinated Beverages/day (How many 12 oz. glasses of caffeinated beverage, including coffee, do you drink in an average day?)	Continuous	536	1.41±1.86 (0-18.0)

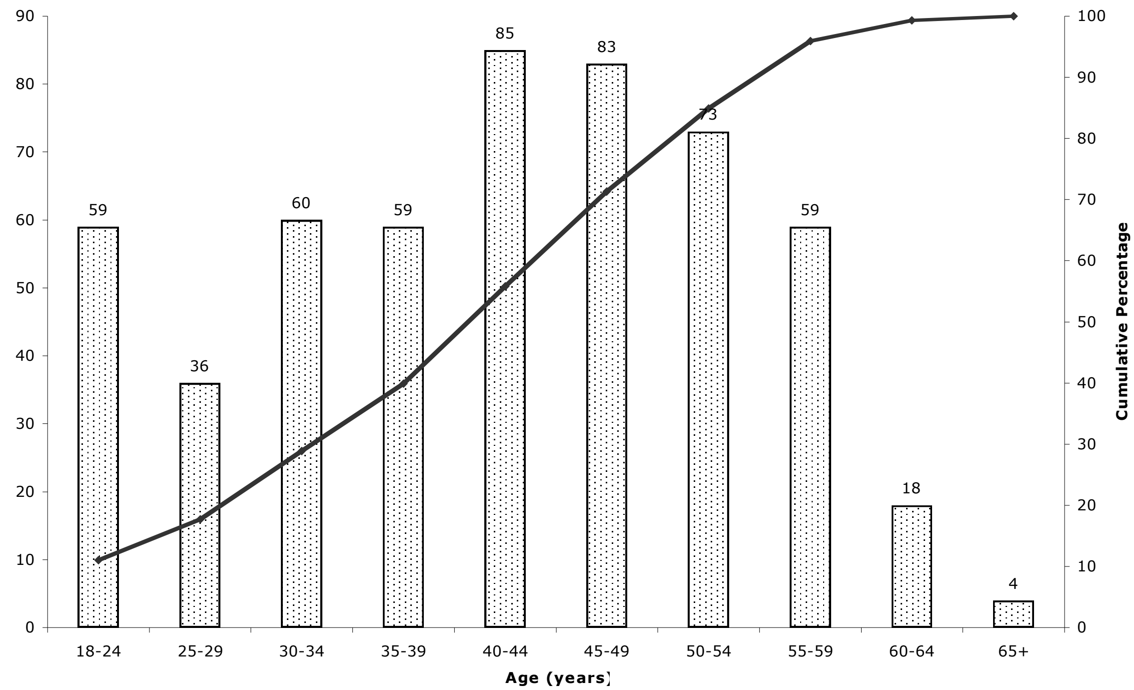

Figure 3.2: Frequency Distribution of Age at Baseline

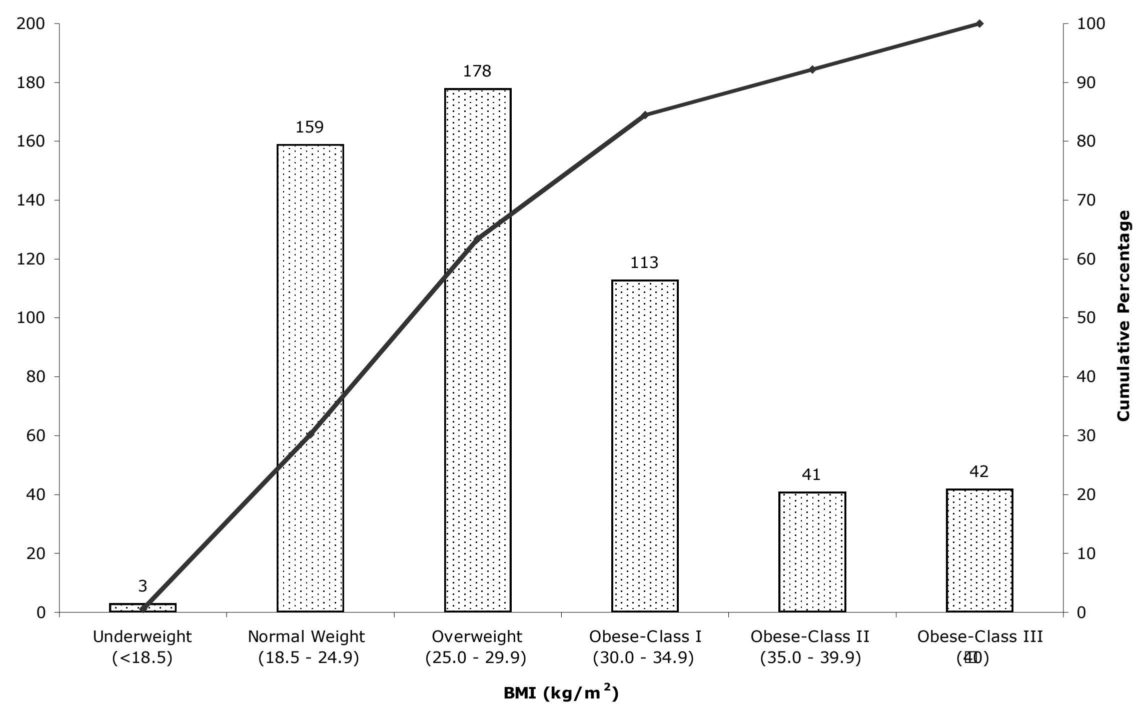

Figure 3.3: Frequency Distribution of BMI at Baseline

3.2.4. Psychosocial Factors:

Personal and job related psychosocial factors are summarized in Tables 3.4 and 3.5. About one out of four workers (24.6%) reported that they often or always had family problems, one out of five workers (19.8%) felt often or always depressed, close to two out of five workers (38.8%) often or always felt physically exhausted after work, more than one out of five workers (20.7%) felt often or always mentally exhausted after work, and a vast majority of the workers (92.3 %) rated their general health as either same or better than that of other people of their own age.

A vast majority of the workers (85.1) reported that their employers cared about their health and safety on the job. A majority of the workers (53.5%) reported that their supervisors often or always appreciated their jobs. Practically all workers (96.3%) reported that they often or always got along with their co-workers and only a few workers (4.8%) were either dissatisfied or very dissatisfied with their jobs. Three out of five workers (58.8%) reported that they would recommend their jobs to someone else and about the same number (60.8%) reported it was likely or very likely that they would take their job again.

3.2.5. Lifetime Prevalence of Non-DUE Diseases at Baseline

Lifetime prevalence of non-DUE diseases is summarized in Table 3.6. Lifetime prevalence includes past history as well diagnoses at baseline by the research team physicians. Prior history of these diseases is based on if their physicians told the workers that they had a specific disease. Of the 536 workers in the study, 16.8% reported that they had high blood pressure. In contrast, baseline measurements of blood pressure showed that 44.0% of the workers were in pre-hypertension stage, 19.6% had stage I high blood pressure and another 8.2% had stage II high blood pressure. One out of 7 workers (14.2%) had high cholesterol, 9.5% had osteoarthritis, and 5.0% had inflammatory arthritis (including rheumatoid arthritis). A small number of workers were told by their physicians that they had: (i) diabetes (4.1%), (ii) gout (1.3%), (iii) kidney failure (0.4%), and/or (iv) thyroid problem (6.2%). Past wrist fractures (left, right or both) were reported by 7.1% of the workers.

3.2.6. Baseline and Lifetime Prevalence of DUE Symptoms and Disorders

The one-month period prevalence and lifetime prevalence at baseline of DUE symptoms and specific disorders are summarized in Table 3.7.

More than one out of four workers (28.7%, 154 workers) had at least one DUE disorder (other than CTS) at baseline based on case definitions utilized in this study. Among those with DUE disorders, most workers had between 1 to 2 disorders (mean = 1.5 ± 0.80, range 1 – 4 disorders/worker). The three most common disorders at baseline were lateral epicondylitis, trigger finger, and CTS; 14.9%, 11.8%, and 10.3% of the workers had these disorders respectively. Lifetime prevalence for these three disorders was 21.8%, 24.6%, and 19.8% respectively. Other disorders at baseline included: (i) medial epicondylitis (4.0%), (ii) deQuervain's (4.4%), (iii) Flexor tendonitis (4.2%) and extensor tendonitis (3.1%).

Lifetime prevalence at baseline for one or more DUE disorders (deQuervain's, hand/wrist tendonitis, trigger finger/thumb, lateral epicondylitis and/or medial epicondylitis) was 56.5% (303 workers). Of these 303 workers, the mean number of DUE disorders was 1.8 ± 1.04 (range: 1 – 6), and 25.0% of the 134 workers had a history of two or more disorders.

At baseline 99 (18.5%) of the workers had CTS symptoms (tingling and/or numbness) and 165 (30.8%) of the workers had abnormal NCS. Out of these workers 28 workers had a NCS consistent with bilateral CTS and 27 with unilateral CTS, resulting in a baseline CTS prevalence of 10.3% (55 workers). Prior to baseline 52 workers (9.7%) had carpal tunnel release surgery or received injections for treatment of CTS. Thus the lifetime prevalence of CTS at baseline was 19.7% (n= 106). One worker was determined to have poly neuropathy based upon NCS.

Table 3.2: Summary of Participants' Hobbies

No.	Hobby	Total N	Number Participating	
			n	%
1.	**Having one or more hobbies**	536	459	85.6
2.	**Computer, Internet**	536	245	45.7%
3.	**Knitting, Sewing, Needlepoint, Crocheting, Arts and Crafts**	536	119	22.2%
4.	**Gardening, Landscaping** (Do you spend time outside of work gardening or landscaping?)	536	280	52.2%
5.	**Piano** (Do you spend time outside of work practicing or playing the piano?)	536	5	0.9%
7.	**Maintenance** (Do you spend time outside of work performing maintenance or mechanical work?)	536	110	20.5%
8.	**Woodworking, Furniture Building or Repair** (Do you spend time outside of work building or repairing furniture or woodworking?)	536	59	11.1%
7.	**Hunting and/or Fishing**	536	44	8.2%
8.	**Remodeling** (Do you spend time remodeling or building a home?)	536	108	20.2%
10.	**Vibrating Tools** (Do you spend time outside of work using tools that shake or shudder?)	536	57	10.6%
11.	**Snowmobiling** (Do you spend time outside of work driving a snowmobile?)	536	24	4.5%
12	**Motorcycling** (Do you spend time driving a motorcycle or ATV?)	536	57	10.6%

Table 3.3: Summary of Participation in Various Exercises

No.	Exercise	Total N	Number Exercising	
			n	%
1.	**Participating in one or more exercises**	536	434	81.0%
2.	**Aerobics, Jazzercise** (Do you participate in aerobics or Jazzercise on a regular basis?)	536	33	6.2%
3.	**Walking** (Do you go walking outside of work on a regular basis for exercise?)	536	263	49.1%
4.	**Running, Jogging** (Do you go running or jogging for exercise on a regular basis?)	536	53	9.9%
5.	**Bicycling** (Do you go bicycling for exercise on a regular basis?)	536	71	13.3%
6.	**Swimming** (Do you go swimming for exercise on a regular basis?)	536	40	7.5%
7.	**Lifting weights** (Do you lift weights for exercise on a regular basis?)	536	88	16.4%
8.	**Baseball** (Do you play baseball on a regular basis?)	536	24	4.5%
9.	**Basketball** (Do you play basketball on a regular basis?)	536	32	6.0%
10.	**Football** (Do you play football on a regular basis?)	536	8	1.5%
11.	**Racquetball** (Do you play racquetball on a regular basis?)	536	2	0.4%
12.	**Handball**	536	0	0%
13.	**Tennis** (Do you play tennis on a regular basis?)	536	10	1.9%
14.	**Snow shoveling**	536	269	50.2%
14.	**Snow Skiing or Snow boarding** (Do you go snow skiing or snowboarding on a regular basis?)	536	8	1.5%
15.	**Water Skiing or Wave Runner** (Do you go water skiing or wave running on a regular basis?)	536	9	1.7%

Table 3.4: Descriptive statistics for personal psychosocial variables

Variable	Category	n	Percentage
Family Problems (How often do you have family problems, which irritate or bother you?)	Never	107	20.0%
	Seldom	297	55.4%
	Often	98	18.3%
	Always	34	6.3%
Felt Depressed (How often during the past year have you felt “down,” blue or depressed?)	Never	130	24.2%
	Seldom	300	56.0%
	Often	100	18.7%
	Always	6	1.1%
Feel Physically Exhausted (How often do you feel physically exhausted after work?)	Never	63	11.8%
	Seldom	265	49.4%
	Often	165	30.8%
	Always	43	8.0%
Feel Mentally Exhausted (How often are you mentally exhausted after work?)	Never	159	29.7%
	Seldom	266	49.6%
	Often	97	18.1%
	Always	14	2.6%
General Health to Others (How is your general health compared to people of your own age?)	Much Better	87	16.2%
	Somewhat Better	181	33.8%
	The Same	216	40.3%
	Somewhat Worse	49	9.1%
	Much Worse	3	0.6%

Table 3.5: Descriptive statistics for job related psychosocial factors

Variable	Category	n	Percentage
Employer Cares (Does your employer care about your health and safety on the job?)	Strongly Agree	114	21.3%
	Agree	241	45.0%
	Neither Agree nor Disagree	101	18.8%
	Disagree	53	9.9%
	Strongly Disagree	27	5.0%
Supervisor Appreciation (Does your supervisor demonstrate appreciation for the work you do?)	Never	46	8.6%
	Seldom	203	37.9%
	Often	194	36.2%
	Always	93	17.3%
Get Along with Co-Workers (Do you get along with your co-workers?)	Never	0	0.0%
	Seldom	20	3.7%
	Often	205	38.3%
	Always	311	58.0%
Job Satisfaction (In all, how satisfied with your job?)	Very Satisfied	106	19.8%
	Satisfied	282	52.6%
	Neither Satisfied nor Dissatisfied	122	22.8%
	Dissatisfied	23	4.3%
	Very Dissatisfied	106	0.5%
Recommend Job (How strongly would you recommend this job to someone else?)	Strongly Recommend	72	13.5%
	Recommend	243	45.3%
	Neither Recommend nor Discourage	142	26.5%
	Discourage	52	9.7%
	Strongly Discourage	27	5.0%
Take Job Again (If you were looking for a new job now, how likely is it that you would take this job again?)	Very Likely	114	21.3%
	Likely	212	39.5%
	Neither Likely Nor Unlikely	75	14.0%
	Unlikely	77	14.4%
	Very Unlikely	114	10.8%

Table 3.6: Descriptive statistics for non-DUE disease and disorder history

Variable	Category	n	Percentage
Diabetes (Have you ever been told by a physician that you have diabetes)	No Yes	514 22	95.9% 4.1%
Gout (Have you ever been told by a physician that you have Gout?)	No Yes	529 7	98.7% 1.3%
High BP (Have you ever been told by a physician that you have high blood pressure?)	No Yes	446 90	83.2% 16.8%
Diastolic Blood Pressure (measured, mm of Hg)	Continuous	536	79.9±10.62 (55-125)
Systolic Blood Pressure (measured, mm of Hg)	Continuous	536	128.3 ±17.19 (92-191)
Blood Pressure Classification (Measured)	Normal Pre-hypertension Stage I High BP Stage II High BP	151 236 105 44	28.2% 44.0% 19.6% 8.2%
Resting Heart Rate (beats/min)	Continuous	536	73.0±10.4 (48-113)
High Cholesterol (Have you ever been told by a physician that you have high cholesterol?)	No Yes	460 76	85.8% 14.2%
Inflammatory Arthritis (Have you ever been diagnosed with Rheumatoid arthritis, lupus, or another inflammatory arthritis?)	No Yes	509 27	95.0% 5.0%
Osteoarthritis (Have you ever been told by a physician that your have osteoarthritis or degenerative arthritis?)	No Yes	485 51	90.5% 9.5%
Kidney Failure (Have you ever been told by a physician that you have kidney failure?)	No Yes	534 2	99.6% 0.4%
Thyroid Problem (Have you ever been told by a physician that you have a thyroid problem?)	No Yes	503 33	93.8% 6.2%
Past Wrist Fracture (Non-hand specific)	No Yes	498 38	92.9% 7.1%
Left Wrist	No Yes	514 22	95.9% 4.1%
Right Wrist	No Yes	519 17	96.8% 3.2%

Table 3.7: Baseline prevalence of DUE specific disorders other than CTS and non-specific pain, and lifetime prevalence of DUE specific disorders other than CTS at the baseline.

Variable	Category	n* (baseline prevalent)	Baseline* Percentage or Mean ±Standard Deviation (Range)	Lifetime** Percentage At baseline
CTS	No	481	89.7%	80.2%
	Yes	55	10.3%	19.8%
CTS				
Left Hand	No	502	93.7%	87.1%
	Yes	34	6.3%	12.9%
Right Hand	No	487	90.9%	81.9%
	Yes	49	9.1%	18.1%
Both Hands	No	508	94.8%	88.8%
	Yes	28	5.2%	11.2%
Polyneuropathy	No	535	99.8%	99.8%
	Yes	1	0.2%	0.2%
deQuervain's	No	511	95.3%	94.8%
	Yes	25	4.7%	5.2%
Trigger Finger	No	473	88.3%	75.4%
	Yes	63	11.7%	24.6%
Flexor Tendonitis	No	515	96.1%	---
	Yes	21	3.9%	
Extensor Tendonitis	No	489	91.2%	---
	Yes	47	8.8%	
Hand/Wrist Tendonitis	No	---	---	82.5%
	Yes			17.5%
Lateral Epicondylitis	No	456	85.1%	76.9%
	Yes	80	14.9%	23.1%
Medial Epiconcylitis	No	513	95.7%	93.1%
	Yes	23	4.3%	6.9%
Aggregate Disorders (One or more disorders)	No	344	64.2%	43.5%
	Yes	192	35.8%	56.5%
Sum of Specific Disorders: baseline *# of Specific DUE Disorders*	Continuous (1 or more disorder)	192	1.6±0.96 (1 - 5)	1.8±1.04 (1 – 6)

* Based on research team physician diagnosis at the baseline

** Based on baseline team physician diagnosis and medical history

3.2.7. Descriptive Statistics for Job Physical Exposure Variables

Job physical exposure variables are divided into three major groups: (i) ratings of perceived exertion for force, (ii) measures of repetitions, (iii) hand/wrist posture and (iv) TLV for HAL and Strain Index scores. All job physical exposure measures varied during the study depending on whether or not workers changed jobs. Descriptive statistics for these variables are provided based on their values at baseline.

On the average, there was little difference between typical exposure and peak exposure values for hand force, repetition, hand/wrist posture and % duration of exertion (Table 3.8). On the average jobs studied required low force, high repetition and fair hand/wrist posture (Table 3.8). Hand force ratings by the workers were a little higher than those provided by the analysts. For typical exposure, mean typical hand force and peak hand force ratings by the workers were 2.81±1.44 and 4.35±1.79 and by the analysts were 1.71±0.82 and 3.71±1.25 respectively. Similar differences were observed for peak exposure. Analysts' overall force rating for typical and peak exposures was 2.37±0.88 and 2.44±0.91. The mean number of efforts per minute for typical and peak exposure were 26.3±14.69 and 27.1±14.87 respectively. HAL ratings for typical and peak exposure were 5.2±1.64 and 5.3±1.71 respectively. Percent duration of exertion was high, 71.6%±17.64 for typical exposure and 72.6%±17.55 for peak exposure. Hand/wrist posture on the SI scale was rated as 3.15±0.54 ("fair") for typical exposure and 3.77±0.90 (close to "bad") for peak exposure. Speed of work was rated as fair for both the typical exposure and peak exposure, 2.96±0.32 and 2.97±0.31 respectively.

The mean TLV for HAL was above the "TLV Limit", both for typical and peak exposures (Table 3.9). As Expected TLV for HAL for peak exposure was a little higher than that for typical exposure. TLVs for HAL calculated using workers ratings of peak force were higher than those using analysts ratings of peak force. Using analyst peak force ratings, the Percentages of workers with TLV for HAL below Action Limit (0.56), between Action Limit and TLV (0.78) and the above the TLV (>0.78) were 24.4%, 33.6% and 42.0% respectively for typical exposure and 23.7%, 31.9% 44.4% for peak exposure (Table 3.9). The mean SI score was 15.1±12.86, and 72.6% of jobs were above a SI score of 6 (cut off point for hazardous jobs recommended by Moore et al. 2006).

Table 3.8: Descriptive statistics for baseline ratings of perceived exertion[1]

Variable	Category	n	Typical Exposure Mean ± Standard Deviation (range)	Peak Exposure Mean ± Standard Deviation (range)
Shift Duration (hrs/day)	Continuous	536	8.4±0.51 (4-12)	---
Number of Jobs Rotations/worker	Continuous	252	3.4±1.6 (2-10)	---
Worker Typical Force Rating *Worker provided Borg CR-10 Rating*	Continuous	536	2.81±1.44 (0.0 – 10.0)	2.88±1.41 (0.0 – 10.0)
Analyst Typical Force Rating *Analyst provided Borg CR-10 Rating*	Continuous	536	1.71±0.82 (0.0 – 4.0)	1.76±0.82 (0.0 – 4.0)
Worker Peak Force Rating *Worker provided Borg CR-10 Rating*	Continuous	536	4.35±1.79 (0.0 – 10.0)	4.43±1.75 (0.0 – 10.0)
Analyst Peak Force Rating *Analyst provided Borg CR-10 Rating*	Continuous	536	3.71±1.25 (0.5 – 10.0)	3.75±1.27 (0.5 – 10.0)
Analyst Overall Force Rating *Analyst provided Borg CR-10 Rating*	Continuous	536	2.36±0.88 (0.5 – 5.0)	2.43±0.91 (0.5-7.0)
Analyst SI Intensity of Exertion *SI scale (1-5)*	Continuous	536	1.43±0.51 (1 – 3)	1.47±0.53 (1 – 4)
HAL Rating *Analyst HAL Rating, verbal anchor scale*	Continuous	536	5.2±1.64 (1.0 – 9.0)	5.3±1.71 (1.0 – 9.0)
Efforts per Minute *Sum of all efforts from task analysis*	Continuous	536	26.3±14.69 (0.8-121.0)	27.1±14.87 (0.8 – 121.0)
Percent Duration of Exertion *Sum of all efforts from task analysis*	Continuous	536	71.6±17.64 (18.0-99.4)	72.6±17.55 (18.0 – 99.4)
SI Posture Rating *SI posture (Moore & Garg, 1995 scale)*	Continuous	536	3.15±0.54 (1.0-5.0)	3.18±0.55 (1.0 – 5.0)
SI Speed of Work Rating *SI speed (Moore & Garg, 1995 scale)*	Continuous	536	2.96±0.32 (2.0-5.0)	2.97±0.31 (2.0 – 5.0)

[1] Descriptive statistics are provided for the baseline exposure of the cohort (n=536). Workers changed exposure up to four times during the course of this study.

Table 3.9: Descriptive statistics for TLV for HAL and SI Scores[1]

Variable	Category	n	Typical Exposure Mean ± Standard Deviation (range)	n	Peak Exposure Mean ± Standard Deviation (range)
TLV for HAL (worker RPE) *Worker Peak RPE, Analyst HAL Rating*	Continuous	536	1.04±0.84 (0.0 – 7.00)	536	1.12±0.99 (0.0 – 8.00)
TLV for HAL (analyst RPE) *Analyst Peak RPE, Analyst HAL Rating*	Continuous	536	0.87±0.62 (0.07 – 6.00)	536	0.92±0.69 (0.07 – 6.00)
TLV for HAL (worker RPE) *Prescribed limits*	< 0.56	110	20.5%	101	18.8%
	≥0.56 - ≤0.78	126	23.5%	121	22.6%
	> 0.78	300	56.0%	314	58.6%
TLV for HAL (analyst RPE) *Prescribed limits*	< 0.56	131	24.4%	127	23.7%
	≥0.56 - ≤0.78	180	33.6%	171	31.9%
	> 0.78	225	42.0%	238	44.4%
TLV for HAL (worker RPE)	≤ 0.83	278	51.9%	269	50.2%
	> 0.83	258	48.1%	267	49.8%
Strain Index Score	Continuous	536	15.13±12.86 (0.8 – 81.0)	536	15.73±13.49 (0.8 – 108.0)
Strain Index Score	≤ 6	147	27.4%	143	26.7%
	> 6	389	72.6%	393	73.3%
Strain Index Score *5 category model*	≤ 6	147	27.4%	143	26.7%
	> 6 - ≤ 12	141	26.3%	131	24.4%
	> 12 - ≤ 18	109	20.3%	111	20.7%
	> 18 - ≤ 24	25	4.7%	30	5.6%
	> 24	114	21.3%	121	22.6%

[1] Descriptive statistics are provided for the baseline exposure of the cohort (n=536). Workers changed exposure up to four times during the course of this study.

4. Results

4.1. Carpal Tunnel Syndrome

Demographics of the cohort eligible to produce an incident case of CTS (n=429) are summarized in Table 4.1. Most of the cohort was female (63.4%) and 67.1% were overweight (BMI 25-29.9 kg/m2) or obese (BMI > 30.0 kg/m^2). Twelve workers (2.8%) reported being diabetic. A majority reported being physically active outside of work with participation in aerobic exercises and/or sports. Many had one or more hobbies such as maintenance work, remodeling, woodworking, gardening and/or playing piano.

Table 4.1: Descriptive Statistics for Job Physical and Other Factors, CTS Eligible Cohort (n=429)

Category	Variable	Categories	Mean ± Std. Dev. or %
Demographic	Age (years)	---	41.2±11.72 (18.7-68.1)
	Gender	Male Female	36.6% 63.4%
	Handedness	Right Left Both Equally	84.9% 9.1% 6.0%
	Family History of CTS	No Yes	81.6% 18.4%
	Pregnancy at baseline (Females only)	No Yes	99.3% 0.7%
	Alcohol Use	No Yes	45.2% 54.8%%
	Currently Smoking	No Yes	65.0% 35.0%
	Ever Smoked	No Yes	42.6% 57.4%
Anthropometric	Body Mass Index (BMI) kg/m^2	Underweight (< 18.5) Normal weight (18.5 – 24.9) Overweight (25.0 – 29.9) Obese Class I (30.0 - 34.9) Obese Class II (35.0-39.9) Obese Class III (≥40.0)	0.5% 32.4% 35.2% 20.0% 5.6% 6.3%
Medical History	History of Diabetes Mellitus	No Yes	97.2% 2.8%
	Thyroid Problem	No Yes	95.8% 4.2%

*Distal Upper Extremity (DUE) Musculoskeletal Disorders (MSDs). These are: lateral epicondylalgia, medial epicondylalgia, deQuervain's, and hand tendinitis (flexor or extensor) trigger digit.

Table 4.1 continued: Descriptive Statistics for Job Physical and Other Factors, CTS Eligible Cohort (n=429)

Category	Variable	Categories	Mean ± Std. Dev. or %
Medical History	Rheumatoid and/or Inflammatory Arthritis	No Yes	95.3% 4.7%
	Osteoarthrosis	No Yes	91.1% 8.9%
	Diagnosed Baseline Prevalence of DUE MSDs*	No Yes	72.3% 27.7%
	Lifetime Prevalence of DUE MSDs* at baseline	No Yes	57.3% 27.7%
	Aggregate (Total Number) DUE Disorders at baseline	0 1 2 3 ≥4	72.3% 17.5% 5.6% 3.2% 1.4%
	Wrist Fracture	No Yes	93.2% 6.8%
Hobbies/Activities	Gardening	No Yes	46.4% 53.6%
	Knitting	No Yes	78.8% 21.2%
	Walking	No Yes	53.2% 46.8%
Psychosocial	Job Satisfaction	Very Satisfied Somewhat Satisfied Neither/Nor Somewhat/Very Dissatisfied	19.6% 52.4% 23.8% 4.2%
	Mentally Exhausted	Never Seldom Often/Always	30.8% 49.4% 19.8%
	General Health Compared to Others	Somewhat/Much Better The Same Somewhat/Much Worse	48.9% 40.6% 10.5%
	Felt Depressed	Never Seldom Often Always	24,0% 57.1% 17.7% 1.2%

*Distal Upper Extremity (DUE) Musculoskeletal Disorders (MSDs). These are: lateral epicondylalgia, medial epicondylalgia, deQuervain's, and hand tendinitis (flexor or extensor) trigger digit.

Table 4.1 continued: Descriptive Statistics for Job Physical and Other Factors, CTS Eligible Cohort (n=429)

Category	Variable	Categories	Mean ± Std. Dev. or %
Job Physical Factors (Typical Job)	Worker Peak Force (RPE)	---	4.3±1.68 (0.5-10.0)
	Efforts per Minute	---	25.6±14.57 (0.8-121.0)
	Typical Hand/Wrist Posture (SI Rating)	Very Good Good Fair Bad Very Bad	0.2% 5.8% 73.2% 19.4.4% 1.4%
	Hand Activity Level (HAL) Rating	---	5.1±1.60 (1.0-9.0)
	Threshold Limit Value (TLV) for HAL, Worker Force Rating	< Action Limit (AL) ≥AL - < TLV ≥TLV	20.5% 23.8% 55.7%
	Strain Index Score, Typical job	---	14.7±12.21 (0.8-81.0)

*Distal Upper Extremity (DUE) Musculoskeletal Disorders (MSDs). These are: lateral epicondylalgia, medial epicondylalgia, deQuervain's, and hand tendinitis (flexor or extensor) trigger digit.

Point prevalence of CTS at baseline was 10.3% and lifetime prevalence of CTS at baseline was 19.8%. There were 429 workers eligible to become a case. During an average of 37.8 months of follow-up there were 35 new CTS cases (n=28, 10.3% of females and n=7, 4.5% of males). All 35 indicated their tingling and numbness was either due to an "unsure" (n=20) cause or was thought to be work-related (n=15). During follow-up there were two CTS incident cases among the 12 diabetics (16.7%).

Table 4.2 summarizes the results from unadjusted univariate analyses for job physical factors as well as relevant covariates for determining possible predictors of increased risk of CTS in multivariate models. The statistically significant factors were: age, gender, BMI, family history of CTS, inflammatory arthritis, osteoarthritis, number of other DUE MSDs at baseline, gardening, knitting, feeling of mental exhaustion, worker peak force exertion rating and SI score using worker peak force rating. Job satisfaction, worker's general health compared to others and SI score using analyst overall force rating were marginally significant (Table 4.2).

Table 4.2: Univariate Hazard Ratios for Job Physical Factors and Covariates with p ≤ 0.10 for CTS Eligible Cohort.

Category	**Variable (overall p-value)**	**Categories**	**HR (95% CI)**	**p-value**
Demographic	Age (years)	≤ 35 >35	1.0 2.8 (1.07 – 7.08)	 0.037
	Gender	Male Female	1.0 2.3 (1.00 – 5.25)	 0.05
	Family History of CTS	No Yes	1.0 2.1 (1.04 – 4.35)	 0.038
Anthropometric	Body Mass Index (BMI) (kg/m^2)	<35 ≥35	1.0 4.3 (2.14 – 8.63)	 <0.001
Medical History	Rheumatoid/ Inflammatory Arthritis	No Yes	1.0 3.8 (1.47 – 9.79)	 0.006
	Osteoarthrosis	No Yes	1.0 2.2 (0.92 – 5.33)	 0.077
	Baseline Prevalence of DUE MSDs* (# of disorders) (p = 0.007)	0 1 2 ≥3	1.0 2.7 (1.22 – 5.80) 3.1 (1.04 – 9.16) 5.6 (1.86 – 16.57)	 0.014 0.043 0.002
Hobbies/ Activities	Gardening	No Yes	1.0 3.4 (1.47 – 7.70)	 0.004
	Knitting	No Yes	1.0 2.5 (1.26-4.87)	 0.009
	Walking	No Yes	1.0 1.9 (0.98-3.84)	 0.06

Table 4.2 continued: Univariate Hazard Ratios for Job Physical Factors and Covariates with p ≤ 0.10 for CTS Eligible Cohort.

Category	Variable (overall p-value)	Categories	HR (95% CI)	p-value
Psychosocial	Job Satisfaction (p = 0.084)	Very Satisfied	1.0	
		Satisfied	2.9 (0.86 – 9.61)	0.313
		Neither/Nor	2.0 (0.52 – 7.76)	0.086
		Dissatisfied / V. Dissatisfied	7.2 (1.45 – 35.78)	0.016
	Mentally Exhausted (p = 0.04)	Never	1.0	
		Seldom	1.1 (0.47-2.67)	0.799
		Often/Always	2.7 (1.13-6.59)	0.026
	General Health Compared to Others (p = 0.060)	Somewhat/Much Better	1.0	
		The Same	1.2 (0.54 – 2.46)	0.706
		Somewhat/Much Worse	3.04 (1.27-7.25)	0.012
Biomechanical Stressors (Typical Exposure)	Peak Force (Worker, Borg CR-10 scale))	≤ 5	1.0	
		> 5	2.5 (1.19 – 5.14)	0.016
	Efforts per Minute	≤ 24	1.0	
		>24	1.5 (0.78 – 2.96)	0.225
	Typical Hand/Wrist Posture (SI Rating)	Very Good, Good, Fair	1.0	
		Bad, Very Bad	0.67 (0.26 – 1.73)	0.406
	Worst Hand/Wrist Posture (SI Rating)	Very Good, Good, Fair	1.0	
		Bad, Very Bad	0.98 (0.49 – 1.95)	0.95
	% Duration of Exertion	≤ 75%	1.0	
		> 75%	1.14 (0.59 – 2.22)	0.694
	Hand Activity Level (HAL) Rating	≤ 4	1.0	
		> 4	1.7 (0.82 – 3.55)	0.154
	Threshold Limit Value (TLV) for HAL (p = 0.229)	< Action Limit (AL)	1.0	
		≥AL - < TLV	0.6 (0.18 – 1.74)	0.310
		≥TLV	1.2 (0.52 – 2.82)	0.660

Table 4.2 continued: Univariate Hazard Ratios for Job Physical Factors and Covariates with $p \leq 0.10$ for CTS Eligible Cohort.

Category	Variable (overall p-value)	Categories	HR (95% CI)	p-value
Biomechanical Stressors (Typical Exposure)	Strain Index Score (p = 0.062) (Analyst Overall Force Rating)	≤ 6	1.0	
		> 6 - ≤ 12	1.5 (0.53 – 4.27)	0.427
		> 12 - ≤ 18	3.3 (1.21 – 8.88)	0.019
		> 18 - ≤ 24	4.9 (1.38 – 17.41)	0.014
		> 24	1.7 (0.53 – 5.14)	0.386
	Strain Index Score (Analyst Overall Force Rating)	≤ 6 > 6	1.0 2.2 (0.92 – 5.37)	0.074
	Strain Index Score (Worker Peak Force Rating)	≤3 6 > 36	1.0 2.2 (1.12 – 4.22)	0.022

*Distal Upper Extremity (DUE) Musculoskeletal Disorders (MSDs) other than CTS.

All analyses for SI, TLV for HAL and peak force are for the workers' typical exposures (Figure 2.2). Typical exposures were selected as they better represent the job physical exposures over an entire work shift. Substituting peak exposures for typical exposures had no material effect on these results with the exception of efforts/min. Efforts/min showed statistically significant relationship with incident cases of CTS for peak exposure (Table 4.3).

The multivariate Cox regression model with time-varying covariates that predicted increased risk of CTS included Strain Index (SI) score > 6, BMI > 35kg/m^2, a diagnosis of one or more DUE muscle-tendon disorders (other than CTS) at baseline, self-reported rheumatoid/inflammatory arthritis, gardening, and feelings of mental exhaustion (see Tables 4.4 and 4.5 for 5- and 2-category SI scores). SI scores significantly predicted increased risk of CTS after controlling for covariates and demonstrated a dose-response relationship up to a SI score of 24 (Table 4.4). Two SI score categories, > 12 to ≤ 18 and > 18 to ≤ 24, had 3.7- and 9.1-fold increased risk (HR) for CTS respectively (Table 4.4). Substituting a simple 2-category SI model for the 5-category model showed a 2.4-fold increased risk (HR) for CTS (Table 4.5). Further simplifying the final models by eliminating either feelings of mental exhaustion or gardening or both improved the association between the job physical measure (SI scores) and the increased risk of CTS. However, AIC scores were higher for the simplified models. The simplified models with 2- and 5-category SI scores had overall p-values of 0.027 and 0.011 for SI score respectively (Tables 4.6 and 4.7). SI scores calculated using worker peak force rating in place of analyst overall force rating also significantly predicted increased risk of CTS (Table 4.8). This modified SI model showed stronger association (HR = 2.53, p = 0.009) as compared to the two category SI model using analyst overall force rating (HR = 2.36, p = 0.065) (Tables 4.5 and 4.8).

Table 4.3: Comparison of Typical and Peak Exposure Analyses for Job Physical Factors. Results are from Multivariate Analyses.

Variable	Category	Typical Exposure HR (95% CI), p-value	Peak Exposure HR (95% CI), p-value
TLV for HAL (worker force) *Worker Peak Force Rating, Analyst HAL Rating, Prescribed Limits*	< AL ≥AL - ≤TLV >TLV	1.00 (overall p = 0.253) 0.48 (0.15 – 1.56), p = 0.224 1.11 (0.47 – 2.63), p = 0.809	1.00 (overall p = 0.085) 0.30 (0.08 – 1.16), p = 0.081 1.17 (0.50 – 2.74) p = 0.718
TLV for HAL (worker force) *Worker Peak Force Rating, Analyst HAL Rating,TLV Raised to 0.84*	≤ 0.84 > 0.84	1.00 2.06 (1.04 – 4.10), p = 0.039	1.00 1.92 (0.97 – 3.81), p = 0.061
Strain Index	≤ 6 > 6	1.00 2.36 (0.95 – 5.86), p = 0.065	1.00 2.27 (0.91 – 5.64), p = 0.079
Strain Index	≤ 6 > 6 - ≤ 12 ≥ 12 - ≤ 18 > 18 - ≤ 24 > 24	1.00 (overall p = 0.009) 1.68 (0.55 – 5.15), p = 0.361 3.72 (1.28 – 10.83), p = 0.016 9.15 (2.38 – 35.21), p = 0.001 1.67 (0.52 – 5.30), p = 0.388	1.00 (overall p = 0.015) 1.56 (0.51 – 4.79), p = 0.436 3.38 (1.20 – 9.47), p = 0.021 7.83 (2.04 – 30.02), p = 0.003 1.55 (0.49 – 4.91), p = 0.457
Strain Index *(Using Worker Peak Force)*	≤ 36 > 36	1.00 2.53 (1.27 – 5.04), p = 0.009	1.00 2.32 (1.17 – 4.59), p = 0.016
Worker Peak Force Rating	≤ 5 > 5	1.00 2.27 (1.06 – 4.89), p = 0.036	1.00 2.00 (0.94 – 4.25), p = 0.070
Efforts per Minute	≤ 24 > 24	1.00 1.70 (0.84 – 3.43), p = 0.139	1.00 2.67 (1.27 – 5.65), p = 0.01

Table 4.4: Multivariate Model for Predicting Incident Cases of CTS with Five-Categories of Strain Index Scores Calculated Using Analyst Overall Force Rating.

Variable	Category	Hazard Ratio	95% C.I.	p-Value
Strain Index Score (p = 0.008)	≤ 6	1.0		
	> 6 - ≤ 12	1.68	0.55 – 5.15	0.361
	> 12 - ≤ 18	3.72	1.28 – 10.83	0.016
	> 18 - ≤ 24	9.15	2.38 – 35.21	0.001
	> 24	1.67	0.52 – 5.30	0.388
Covariates				
Body Mass Index (kg/m^2)	< 35	1.0		
	≥ 35	5.09	2.43 – 10.62	< 0.001
Number of Specific DUE MSDs (Other than CTS) (p = 0.021)	0	1.0	---	---
	1-2	2.09	1.01 – 4.32	0.048
	≥ 3	4.15	1.31 – 13.13	0.015
Rheumatoid/Inflammatory Arthritis	No	1.0		
	Yes	4.31	1.50 – 12.45	0.007
Gardening	No	1.0		
	Yes	3.21	1.38 – 7.48	0.007
Felt Mentally Exhausted (p = 0.035)	Never	1.0		
	Seldom	1.19	0.48 – 2.96	0.707
	Often/Always	2.83	1.01 – 4.32	0.048

Table 4.5: Multivariate Model for Predicting Incident Cases of CTS with Two Categories of Strain Index Scores Calculated Using Analyst Overall Force Rating.

Variable	Category	Hazard Ratio	95% C.I.	p-Value
Strain Index Score	≤ 6	1.0		
	> 6	2.36	0.95 – 5.86	0.065
Covariates				
Body Mass Index (kg/m$^{2)}$)	< 35	1.0		
	≥ 35	5.08	2.41 – 10.72	< 0.001
Number of Specific DUE MSDs (Other than CTS) (p = 0.044)	0	1.0	---	---
	1-2	1.39	0.61 – 3.14	0.436
	≥ 3	4.69	1.38 – 15.98	0.014
Rheumatoid/Inflammatory Arthritis	No	1.0		
	Yes	3.88	1.42 – 10.63	0.008
Gardening	No	1.0		
	Yes	3.11	1.33 – 7.24	0.009
Felt Mentally Exhausted (p = 0.058)	Never	1.0		
	Seldom	1.15	0.46 – 2.85	0.769
	Often/Always	2.54	1.03 – 6.30	0.044

Table 4.6: Simplified Multivariate Model for Predicting Incident Cases of CTS with Five-Categories of Strain Index Scores Calculated Using Analyst Overall Force Rating.

Variable	Category	Hazard Ratio	95% C.I.	p-Value
Strain Index Score (p = 0.012)	≤ 6	1.0		
	> 6 - ≤ 12	1.94	0.66 – 5.76	0.231
	> 12 - ≤ 18	4.20	1.49 – 11.85	0.007
	> 18 - ≤ 24	7.95	2.12 – 29.76	0.002
	> 24	2.11	0.67 – 6.70	0.204
Covariates				
Body Mass Index (kg/m^2)	< 35	1.0		
	≥ 35	4.68	2.25 – 9.77	< 0.001
Number of Specific DUE MSDs (Other than CTS) (p = 0.105)	0	1.0	---	---
	1-2	1.69	0.75 – 3.79	0.205
	≥ 3	3.36	0.97 – 11.71	0.057
Rheumatoid/Inflammatory Arthritis	No	1.0		
	Yes	4.61	1.71 – 12.43	0.003

Table 4.7: Simplified Multivariate Model for Predicting Incident Cases of CTS with Two Categories of Strain Index Scores Calculated Using Analyst Overall Force Rating.

Variable	Category	Hazard Ratio	95% C.I.	p-Value
Strain Index Score	≤ 6	1.0		
	> 6	2.79	1.13 – 6.91	0.027
Covariates				
Body Mass Index (kg/m$^{2)}$)	< 35	1.0		
	≥ 35	4.42	2.13 – 9.18	< 0.001
Number of Specific DUE MSDs other than CTS (p = 0.060)	0	1.0	---	---
	1-2	1.67	0.75 – 3.72	0.211
	≥ 3	3.92	1.17 – 13.22	0.027
Rheumatoid/Inflammatory Arthritis	No	1.0		
	Yes	4.51	1.71 – 11.88	0.002

Table 4.8 Multivariate Model for Predicting Incident Cases of CTS with Two-Categories of Strain Index Scores Calculated Using Worker Peak Force Rating.

Variable	Category	Hazard Ratio	95% C.I.	p-Value
Strain Index Score	≤ 36 > 36	1.0 2.53	1.27– 5.04	0.009
Covariates				
Body Mass Index (kg/m^2)	< 35 ≥ 35	1.0 5.11	2.53 – 10.32	< 0.001
Rheumatoid/Inflammatory Arthritis	No Yes	1.0 4.18	1.51 – 11.57	0.006
Gardening/knitting	No Yes	1.0 2.6	1.12 – 6.03	0.027
Felt Mentally Exhausted (p = 0.049)	Never Seldom Often/Always	1.0 1.08 2.51	 0.44 – 2.66 1.02 – 6.19	 0.863 0.046

Somewhat surprisingly, female gender and age were not associated with an increased risk of CTS in the final models, despite having association in univariate analyses (10.3% female cases vs. 4.5% male cases, HR = 2.3; HR =2.8 for workers older than 35 years of age). Final models showed no statistically significant associations between job satisfaction and increased risk of CTS (see Tables 4.4 and 4.5). No evidence of association was found between pregnancy, thyroid problems, alcohol consumption or history of smoking (currently or ever).

There was no evidence of association between the TLV for HAL and increased risk of CTS either in univariate or multivariate analyses (overall p = 0.25) when using the ACGIH (2002) prescribed Action Limit (AL) and Threshold Limit Value (TLV). In multivariate analyses the TLV for HAL had a HR = 0.48 (95% CI = 0.15-1.56, p = 0.22) when at or above the AL and HR = 1.11 (95% CI = 0.47-2.63 p = 0.81 when above the TLV). However, a simplified two-category model for the TLV for HAL (physical exposure ≤ TLV and exposure > TLV) with the TLV value (peak force/(10-HAL)) raised from 0.78 to 0.84 showed evidence of increased risk for CTS with HR =2.24 (95% CI = 1.15-4.37, p =0.02). In the multivariate analyses, the raised limit for TLV for HAL showed evidence of association (p = 0.04) with a HR of 2.06 (95% CI = 1.04-4.10) (Table 4.9).

Table 4.9: Multivariate Model for Predicting Incident Cases of CTS with the Threshold Limit Value for Hand Activity Level (TLV for HAL) using Two Categories for TLV for HAL and Increasing the TLV Above Published Criteria to 0.84*

Variable	Category	Hazard Ratio	95% C.I.	p-Value
TLV for HAL *2 category model, TLV raised to 0.84 from 0.78*	≤ 0.84 > 0.84	1.0 2.06	 1.04-4.10	 0.039
Covariates				
Body Mass Index (kg/m^{2})	< 35 ≥ 35	1.0 4.67	 2.23 – 9.81	 < 0.001
Number of Specific DUE MSDs other than CTS (p = 0.034)	0 1-2 ≥ 3	1.0 1.39 4.99	--- 0.62 – 3.12 1.46 – 17.05	--- 0.436 0.014
Rheumatoid/Inflammatory Arthritis	No Yes	1.0 3.84	 1.38 – 10.68	 0.010
Gardening	No Yes	1.0 3.32	 1.43 – 7.74	 0.005
Felt Mentally Exhausted (p = 0.043	Never Seldom Often/Always	1.0 1.22 2.74	 0.48 – 3.07 1.09 – 6.88	 0.420 0.010

*The TLV for HAL as published did not provide a measure for statistically significant increased risk of CTS. When the TLV was increased from 0.78 to 0.84, data became statistically significant.

Regarding individual job physical exposure variables, worker peak force rating of ≥ 5 on the Borg CR-10 scale showed evidence for an increased risk of CTS in multivariate analyses (HR = 2.27, 95% CI = 1.06-4.89, p = 0.04) (Table 4.10). High repetition (efforts/min) showed no statistically significant association (p = 0.14) with increased risk of CTS in multivariate analyses of typical exposure. The hazard ratio for efforts/min >24 was 1.7 (95% CI = 0.84-3.43). Efforts per minute was predictive when analyzed for peak exposure (HR = 2.7, 95%CI = 1.27-5.65, p = 0.01). There was no evidence of association between either typical or worst hand/wrist posture and increased risk for CTS. A modified SI model using worker peak force rating showed the strongest association (p = 0.009) compared to any of the individual job physical variables (force, repetition or posture, p ≥ 0.036).

Table 4.10: Multivariate Model for Predicting Incident Cases of CTS with Two- Worker Peak Force Rating.

Variable	Category	Hazard Ratio	95% C.I.	p-Value
Worker Peak Force Rating	≤ 5	1.0		
	> 5	2.27	1.06– 4.89	0.036
Covariates				
Body Mass Index (kg/m^2)	< 35	1.0		
	≥ 35	4.77	2.34 – 9.69	< 0.001
Rheumatoid/Inflammatory Arthritis	No	1.0		
	Yes	3.86	1.40 – 10.64	0.009
Gardening/knitting	No	1.0		
	Yes	2.47	1.06 – 5.75	0.037
Felt Mentally Exhausted (p = 0.055)	Never	1.0		
	Seldom	1.09	0.44 – 2.67	0.855
	Often/Always	2.49	1.01 – 6.18	0.048

4.2. Results: Lateral Epicondylitis

Demographics of the cohort eligible to produce incident cases of lateral epicondylitis (n=412) are summarized in Table 4.11. Most of the cohort was female (62.9%) and 68.7% were overweight (BMI 25-29.9 kg/m2) or obese (BMI>30.0 kg/m2). Thirteen (3.2%) reported being diabetic. A majority reported being physically active outside of work with participation in aerobic exercises and/or sports. Many had one or more hobbies such as maintenance work, remodeling, woodworking, gardening and/or knitting.

Point prevalence of lateral epicondylitis at baseline was 14.9% and lifetime prevalence of lateral epicondylitis at baseline was 23.1%. There were 412 workers eligible to become a case. During an average of 37.8 months of follow-up there were 69 new lateral epicondylitis cases (n=51, 19.7% of females and n=18, 11.8% of males). Out of these 69 cases, 26 indicated their symptoms were either due to an "unsure" cause, 41 indicated they were work-related and two thought they were due to something outside of work other than an acute injury.

Table 4.12 summarizes the results from unadjusted univariate analyses for job physical factors as well as relevant covariates for determining possible predictors of increased risk of lateral epicondylitis in multivariate models. The statistically significant factors were: age > 35 years, high cholesterol, maintenance work outside of regular work, job satisfaction, feelings of depression, worker peak force rating, SI score (calculated using worker peak force rating) and TLV for HAL. BMI (≥ 25), gardening, playing baseball and SI score calculated using analyst's overall force rating were marginally significant ($p \leq 0.10$).

All analyses for SI and TLV for HAL are for the worker's typical exposure (Figure 2.2). Typical exposures were selected as they better represent job physical exposures over an entire work shift. Substituting peak exposures for typical exposures had no material effect on these results (data not reported).

The multivariate Cox regression model with time-varying covariates that predicted increased risk of lateral epicondylitis included Strain Index (SI) score > 8, age > 35, playing baseball, and feelings of depression (Table 4.13). SI scores significantly predicted increased risk of lateral epicondylitis after controlling for covariates ($p \leq 0.043$). A SI score of > 8 had 1.8-fold increased risk (HR) for lateral epicondylitis. Substituting worker peak force rating for analyst overall force rating resulted in a slight improvement in effect magnitude (HR = 2.1) and an improved strength of statistical association (p =0.003) (Table 4.14).

Female gender was not associated with increased risk of lateral epicondylitis in the final models, despite appearing to have greater risk in univariate analysis (19.7% vs. 11.8% cases, HR = 1.56, p = 0.107). Similarly, BMI showed marginal increased risk in univariate analyses (HR=1.6, p = 0.095) but was not associated with increased risk in the final models. Final models showed no statistically significant associations between job satisfaction and increased risk of lateral epicondylitis (see Tables 4.13 and 4.14). No evidence of association was found with pregnancy, thyroid problems, alcohol consumption or history of smoking (currently or ever).

There was evidence of association between the TLV for HAL and increased risk of lateral epicondylitis using the ACGIH (2002) prescribed Action Limit (AL) and Threshold Limit Values (TLV) (Table 4.15). However, it should be noted that job physical exposure ≥ AL and ≤ TLV showed a *reduced* risk of lateral epicondylitis (HR = 0.7) as compared to exposure < AL

Table 4.11: Descriptive Statistics for Job Physical and Other Factors, Lateral Epicondylitis Eligible Cohort (n=412)

Category	**Variable**	**Categories**	**Mean ± Std. Dev. or %**
Demographic	Age (years)	---	41.1±11.91 (18.7-68.1)
	Gender	Male Female	37.1% 62.9%
	Handedness	Right Left Both Equally	84.9% 9.5% 5.6%
	Pregnancy at baseline (Females only)	No Yes	99.2% 0.8%
	Alcohol Use	No Yes	44.7% 55.3%
	Currently Smoking	No Yes	67.7% 32.3%
	Ever Smoked	No Yes	44.9% 55.1%
Anthropometric	Body Mass Index (BMI) kg/m^2	Underweight (< 18.5) Normal weight (18.5 – 24.9) Overweight (25.0 – 29.9) Obese Class I (30.0 – 34.9) Obese Class II (35.0-39.9) Obese Class III (≥ 40)	0.5% 30.8% 34.0% 20.1% 7.3% 7.3%
Medical History	History of Diabetes Mellitus	No Yes	96.8% 3.2%
	Thyroid Problem	No Yes	93.7% 6.3%
	Rheumatoid and/or Inflammatory Arthritis	No Yes	96.4% 3.6%
	Osteoarthrosis	No Yes	91.3% 8.7%
	Diagnosed Baseline Prevalence of DUE MSDs*	No Yes	76.9% 23.1%
	Lifetime Prevalence of DUE MSDs* at baseline	No Yes	59.2% 40.8%
	Aggregate (Total Number) DUE MSDs* at baseline	0 1 2 ≥3	76.9% 16.3% 5.1% 1.7%
	Wrist Fracture	No Yes	92.5% 7.5%

*Distal Upper Extremity (DUE) Musculoskeletal Disorders (MSDs). These are: CTS, medial epicondylalgia, deQuervain's, hand tendinitis (flexor or extensor), trigger digit.

Table 4.11 continued: Descriptive Statistics for Job Physical and Other Factors, Lateral Epicondylitis Eligible Cohort (n=412)

Category	Variable	Categories	Mean ± Std. Dev. or %
Hobbies/Activities	Gardening	No Yes	49.3% 50.7%
	Knitting	No Yes	78.4% 21.6%
	Walking	No Yes	51.2% 48.8%
	Baseball	No Yes	95.2% 4.8%
Psychosocial	Job Satisfaction	Very Satisfied Satisfied Neither/Nor Dissatisfied /Very Dissatisfied	20.6% 51.0% 23.8% 4.6%
	Mentally Exhausted	Never Seldom Often/Always	31.6% 49.3% 19.1%
	General Health Compared to Others	Somewhat/Much Better The Same Somewhat/Much Worse	49.3% 40.5% 10.2%
	Felt Depressed	Never Seldom Often Always	26.5% 49.3% 16.7% 2.4%
Job Physical Factors (Typical Job)	Worker Peak Force (RPE)	---	4.4±1.80 (0.5-10.0)
	Efforts per Minute	---	25.8±14.88 (0.8-121.0)
	Typical Hand/Wrist Posture (SI Rating)	Very Good Good Fair Bad Very Bad	0.2% 5.6% 74.3% 18.9% 1.0%
	Hand Activity Level (HAL) Rating	---	5.1±1.60 (1.0-9.0)
	Threshold Limit Value (TLV) for HAL, Worker Force Rating	< Action Limit (AL) ≥AL - < TLV ≥TLV	21.1% 23.3% 55.6%
	Strain Index Score, Typical job	---	14.6±12.58 (0.8-81.0)

*Distal Upper Extremity (DUE) Musculoskeletal Disorders (MSDs). These are: CTS, medial epicondylalgia, deQuervain's, hand tendinitis (flexor or extensor), trigger digit.

(Table 4.15). A simplified, two- category model for the TLV for HAL was constructed (physical exposure ≤ TLV and exposure > TLV) with the TLV value (peak force/(10-HAL)) raised from 0.78 to 0.87. This revised model showed evidence of increased risk for lateral epicondylitis with HR =2.28 and $p < 0.001$ (Table 4.16).

In multivariate analyses, there was no evidence of statistical association between individual job physical exposure variables (typical force, peak force, repetitions/min, HAL rating or hand/wrist posture) and incident cases of lateral epicondylitis ($p \geq 0.117$). Table 4.17 provides multivariate analysis for peak worker force rating.

Table 4.12: Univariate Hazard Ratios for Job Physical Factors and Covariates with $p \leq 0.10$ for Lateral Epicondylitis Eligible Cohort.

Category	Variable (overall p-value)	Categories	HR (95% CI)	p-value
Demographic	Age (years)	≤ 35 >35	1.0 2.83 (1.48 – 5.39)	0.002
	Gender	Male Female	1.0 1.56 (0.91 – 2.67)	0.11
	Smoking	No Yes	1.0 1.01 (0.6 – 1.69)	0.982
Anthropometric	Body Mass Index (BMI) ($kg/m^{2)}$	<25 ≥25	1.0 1.63 (0.92 – 2.88)	0.095
Medical History	Rheumatoid/ Inflammatory Arthritis	No Yes	1.0 1.52 (0.55 - 4.17)	0.417
	Osteoarthrosis	No Yes	1.0 1.38 (0.66 - 2.89)	0.388
	Diabetes	No Yes	1.0 1.37 (0.43 - 4.36)	0.592
	Thyroid	No Yes	1.0 1.02 (0.41 - 2.54)	0.963
	High Cholesterol	No Yes	1.0 1.80 (1.00 - 3.25)	0.049
	Baseline Prevalence of CTS	No Yes	1.0 1.75 (0.87 – 3.53)	0.119
	Baseline Prevalence of DUE MSDs*	No Yes	1.0 1.23 (0.71 - 2.13)	0.463
Hobbies/ Activities	Gardening	No Yes	1.0 1.55 (0.96-2.52)	0.075
	Knitting	No Yes	1.0 0.94 (0.53-1.67)	0.837
	Walking?	No Yes	1.0 1.22 (0.76-1.96)	0.404

*Distal Upper Extremity (DUE) Musculoskeletal Disorders (MSDs) other than Lateral Epicondylitis

Table 4.12 continued: Univariate Hazard Ratios for Job Physical Factors and Covariates with p ≤ 0.10 for Lateral Epicondylitis Eligible Cohort.

Category	Variable (overall p-value)	Categories	HR (95% CI)	p-value
Hobbies/ Activities	Baseball	No Yes	1.0 2.1 (0.98-4.68)	 0.057
	Swimming	No Yes	1.0 2.02 (1.00-4.07)	 0.050
	Aerobics	No Yes	1.0 1.53 (0.66 – 3.54)	 0.318
	Maintenance Work	No Yes	1.0 0.39 (0.18-0.85)	 0.018
	Remodeling	No Yes	1.0 1.45 (0.82 – 2.57)	 0.202
Psychosocial	Job Satisfaction (p = 0.507)	Very Satisfied Satisfied Neither/Nor Dissatisfied / Very Dissatisfied	1.0 1.24 (0.67 – 2.29) 0.96 (0.45 – 2.06) 2.23 (0.73 – 6.79)	 0.495 0.924 0.160
	Mentally Exhausted (p = 0.110)	Never Seldom Often/Always	1.0 1.78 (0.99 – 3.19) 1.77 (0.87 - 3.57)	 0.054 0.114
	Felt Depressed (p=0.048)	Never Seldom Often/Always	1.0 2.03 (1.05-3.95) 2.29 (1.05-5.0)	 0.036 0.037
Biomechanical Stressors (Typical Exposure)	Peak Force (Worker, Borg CR-10 scale))	≤ 4 > 4	1.0 1.60 (1.0 – 2.57)	 0.051
	Overall Force (Analyst, Borg CR-10)	≤ 3 > 3	1.0 1.25 (0.57 – 2.73)	 0.578
	Efforts per Minute	≤ 19 >19	1.0 1.51 (0.9 – 2.54)	 0.123
	Typical Hand/Wrist Posture (SI Rating)	Very Good, Good, Fair Bad, Very Bad	1.0 0.88 (0.54 – 1.44)	 0.612
	% Duration of Exertion	≤ 50% > 50%	1.0 1.64 (0.71 – 3.79)	 0.247
	Hand Activity Level (HAL) Rating	≤ 4 > 4	1.0 1.51 (0.91 – 2.49)	 0.108

*Distal Upper Extremity (DUE) Musculoskeletal Disorders (MSDs) other than Lateral Epicondylitis

Table 4.12 continued: Univariate Hazard Ratios for Job Physical Factors and Covariates with p ≤ 0.10 for Lateral Epicondylitis Eligible Cohort.

Category	Variable (overall p-value)	Categories	HR (95% CI)	p-value
Biomechanical Stressors (Typical Exposure)	Threshold Limit Value (TLV) for HAL (p = 0.023)	< Action Limit (AL) ≥AL - < TLV ≥TLV	1.0 0.95 (0.40-2.24) 1.95 (0.98 – 3.84)	 0.907 0.056
	Threshold Limit Value (TLV) for HAL (2-Category Model, TLV Raised to 0.87)	< TLV ≥ TLV	1.0 2.35 (1.46-3.78)	 <0.001
	Strain Index Score (Analyst Overall Force Rating) (p = 0.049)	≤ 8 > 8 - ≤ 13 > 13	1.0 2.18 (1.16-4.11) 1.59 (0.84-2.88)	 0.016 0.156
	Strain Index Score (Analyst Overall Force Rating)	≤ 8 > 8	1.0 1.61 (0.93 – 2.78)	 0.090
	Strain Index Score (Worker Peak Force Rating)	≤ 36 > 36	1.0 2.05 (1.27 – 3.28)	 0.003

*Distal Upper Extremity (DUE) Musculoskeletal Disorders (MSDs) other than Lateral Epicondylitis

Table 4.13 Multivariate Model for Predicting Incident Cases of Lateral Epicondylitis with Two Categories of Strain Index Scores Calculated using Analyst Overall Force Rating.

Variable	Category	Hazard Ratio	95% C.I.	p-Value
Strain Index Score	≤ 8 > 8	1.0 1.79	 1.02-3.16	 0.043
Covariates				
Age (years)	≤ 35 > 35	1.0 3.30	 1.68 – 6.47	 < 0.001
Baseball	No Yes	1.0 3.89	 1.71-8.86	 0.001
Felt Depressed (p = 0.085)	Never Seldom Often/Always	1.0 1.98 2.26	 1.02-3.85 1.04-4.92	 0.043 0.041

Table 4.14: Multivariate Model for Predicting Incident Cases of Lateral Epicondylitis with Two Categories of Strain Index Scores Calculated Using Worker Peak Force Rating.

Variable	Category	Hazard Ratio	95% C.I.	p-Value
Strain Index Score	≤ 36 > 36	1.0 2.10	 1.30 -3.41	 0.003
Covariates				
Age (years)	≤ 35 > 35	1.0 3.47	 1.75 – 6.91	 < 0.001
Baseball	No Yes	1.0 4.16	 1.79 - 9.69	 <0.001
Felt Depressed (p = 0.091)	Never Seldom Often/Always	1.0 2.04 2.09	 1.05 - 3.97 0.96 - 4.57-	 0.035 0.064

Table 4.15: Multivariate Model for Predicting Incident Cases of Lateral Epicondylitis with the Threshold Limit Value for Hand Activity Level (TLV for HAL) using Published TLV Limits

Variable	Category	Hazard Ratio	95% C.I.	p-Value
TLV for HAL (p = 0.028)	< Action Limit (AL) ≥AL - < TLV ≥TLV	1.0 0.70 1.68	 0.29 - 1.69 0.87-3.24	 0.423 0.122
Covariates				
Age (years)	≤ 35 > 35	1.0 3.26	 1.67 – 6.37	 <0.001
Baseball	No Yes	1.0 3.12	 1.38– 7.04	 0.006
Felt Depressed (p = 0.103)	Never Seldom Often/Always	1.0 1.94 2.16	 1.00 – 3.77 0.99 – 4.72	 0.050 0.052

Table 4.16: Multivariate Model for Predicting Incident Cases of Lateral Epicondylitis with the Threshold Limit Value for Hand Activity Level (TLV for HAL) using Two Categories for TLV for HAL and Raising the TLV Above Published Criteria to 0.87*

Variable	Category	Hazard Ratio	95% C.I.	p-Value
TLV for HAL *2 category model, TLV raised to 0.87 from 0.78*	≤ 0.87 > 0.87	1.0 2.28	 1.41-3.68	 < 0.001
Covariates				
Age (years)	≤ 35 > 35	1.0 3.11	 1.59 – 6.1	 0.001
Baseball	No Yes	1.0 3.47	 1.54 – 7.83	 0.003
Felt Depressed (p = 0.043	Never Seldom Often/Always	1.0 1.96 2.12	 1.01 – 3.80 0.97 – 4.63	 0.047 0.059

*The TLV for HAL as published did provide a measure for statistically significant increased risk of lateral epicondylitis. However, when the TLV was simplified and raised from 0.78 to 0.87, the model performance improved slightly.

Table 4.17: Multivariate Model for Predicting Incident Cases of Lateral Epicondylitis with Worker Peak Force Rating

Variable	**Category**	**Hazard Ratio**	**95% C.I.**	**p-Value**
Worker Peak Force Rating	≤ 4.0 > 4.0	1.0 1.46	 0.91 - 2.35	 0.117
Covariates				
Age (years)	≤ 35 > 35	1.0 3.43	 1.74 – 6.77	 <0.001
Baseball	No Yes	1.0 3.52	 1.55 – 8.01	 0.003
Felt Depressed (p = 0.103)	Never Seldom Often/Always	1.0 1.95 2.16	 1.00 – 3.78 0.99 – 4.72	 0.049 0.054

4.3. Results: ‘Any Specific Disorder’

Demographics of the virgin cohort with no prior history of any DUE MSD eligible to produce incident cases of any DUE MSD (n=233) are summarized in Table 4.18. A majority of the cohort was female (55.8%) and 67.8% were overweight (BMI 25-29.9 kg/m2) or obese (BMI>30.0 kg/m2). Only four (1.7%) reported being diabetic. A majority reported being physically active outside of work with participation in aerobic exercises and/or sports. Many had one or more hobbies such as gardening and/or knitting.

Point prevalence of any DUE MSD at baseline was 35.8% and lifetime prevalence of CTS at baseline was 56.5% (out of 536 workers). There were 233 workers eligible to become a case. During an average of 37.8 months of follow-up there were 82 new any DUE MSD cases (n=58, 44.6% of females and n=24, 23.3% of males).

Table 4.19 summarizes the results from unadjusted univariate analyses for job physical factors as well as relevant covariates for determining possible predictors of increased risk of any DUE MSD in multivariate models. The statistically significant factors were: age, gender, feelings of mental exhaustion after work, worker peak and typical force ratings, efforts/min, SI scores calculated using analyst overall force rating and worker peak force rating, and a simplified, 2-category TLV for HAL with TLV raised to 0.87 from 0.78.

All analyses for SI and TLV for HAL are for the worker’s typical exposures (Figure 2.2). Typical exposures were selected as they better represent the job physical exposures over an entire work shift. Substituting peak exposures for typical exposures had no material effect on these results (data not reported).

The multivariate Cox regression model with time-varying covariates that predicted increased risk of CTS included worker peak force rating > 5, efforts/min > 22, Strain Index (SI) score > 7 calculated using worker peak force rating, simplified 2-category TLV for HAL with TLV raised to 0.87, age > 38 years and gender (see Tables 4.20 to 4.26). SI scores calculated using the analyst overall force rating while significant in univariate analysis were not associated with an increased risk of any DUE MSD in the adjusted model (p >0.2) (Table 4.20). However, SI scores calculated using worker peak force rating significantly predicted increased risk of any DUE MSD after controlling for covariates and demonstrated a dose-response relationship (Table 4.21). SI scores >36 had almost 3-fold increased risk (HR) for any DUE MSD (Table 4.21). Substituting a simple 2-category SI model for the 3-category model showed a 2.1-fold increase in risk (HR) for any DUE MSD (Table 4.22).

Both age > 38 years and female gender were associated with an increased risk of any DUE MSD in the final models. Final models showed no statistically significant associations with any psychosocial factors (see Tables 4.21 and 4.22). No evidence of association was found for pregnancy, thyroid problems, alcohol consumption and history of smoking (currently or ever). Similarly, none of the hobbies and physical activities outside of work was associated with an increased risk of any DUE MSD.

There was no evidence of association between the TLV for HAL and increased risk of any DUE MSD either in univariate or multivariate analyses using the ACGIH (2002) prescribed Action Limit (AL) and Threshold Limit Values (TLV) (Table 4.23. However, after exploration of the data, a simplified, two-category model for the TLV for HAL was constructed (physical exposure

≤ TLV and exposure > TLV) with the TLV value (peak force/(10-HAL)) raised from 0.78 to 0.87. In the multivariate analyses, the raised limit for TLV for HAL showed evidence of association ($p = 0.02$) with a HR of 1.73 (95% CI = 1.10-2.71) (see Table 4.24).

Table 4.18: Descriptive Statistics for Job Physical and Other Factors, Any Disorder Eligible Cohort (n=233)

Category	**Variable**	**Categories**	**Mean ± Std. Dev. or %**
Demographic	Age (years)	---	39.6±12.1 (18.7-68.1)
	Gender	Male Female	44.2% 55.8%
	Handedness	Right Left Both Equally	84.6% 9.4% 6.0%
	Family History of CTS	No Yes	85.4% 14.6%
	Pregnancy at baseline (Females only)	No Yes	98.5% 1.5%
	Alcohol Use	No Yes	47.6% 52.4%
	Currently Smoking	No Yes	70.4% 29.6%
	Ever Smoked	No Yes	48.1% 51.9%
Anthropometric	Body Mass Index (BMI) kg/m^2	Underweight (< 18.5) Normal weight (18.5 – 24.9) Overweight (25.0 – 29.9) Obese Class I (30.0 – 34.9) Obese Class II (35.0-39.9) Obese Class III (≥ 40)	0.4% 31.8% 35.6% 20.2% 6.4% 5.6%
Medical History	History of Diabetes Mellitus	No Yes	98.3% 1.7%
	Thyroid Problem	No Yes	96.1% 3.9%
	Rheumatoid and/or Inflammatory Arthritis	No Yes	100% 0%
	Osteoarthrosis	No Yes	94.4% 5.6%
	Wrist Fracture	No Yes	92.3% 7.7%

Table 4.18 continued: Descriptive Statistics for Job Physical and Other Factors, Any Disorder Eligible Cohort (n=233)

Category	**Variable**	**Categories**	**Mean ± Std. Dev. or %**
Hobbies/Activities	Gardening	No Yes	49.4% 50.6%
	Knitting	No Yes	84.1% 15.9%
	Walking	No Yes	55.4% 44.6%
	Baseball	No Yes	95.7% 4.3%
Psychosocial	Job Satisfaction	Very Satisfied Satisfied Neither/Nor Dissatisfied /Very Dissatisfied	22.3% 51.9% 22.3% 3.5%
	Mentally Exhausted	Never Seldom Often/Always	32.6% 49.8% 17.6%
	General Health Compared to Others	Much Better Somewhat Better The Same Somewhat/Much Worse	14.1% 33.5% 42.5% 9.9%
	Felt Depressed	Never Seldom Often Always	28.8% 55.3% 14.2% 1.7%
Job Physical Factors (Typical Job)	Worker Peak Force (RPE)	---	4.3±1.74 (0.5-10.0)
	Efforts per Minute	---	25.9±15.38 (1.6-121.0)
	Typical Hand/Wrist Posture (SI Rating)	Very Good Good Fair Bad Very Bad	0.4% 6.4% 73.0% 19.3% 0.9%
	Hand Activity Level (HAL) Rating	---	5.0±1.56 (1.0-9.0)
	Threshold Limit Value (TLV) for HAL, Worker Force Rating	< Action Limit (AL) ≥AL - < TLV ≥TLV	21.0% 24.9% 54.1%
	Strain Index Score, Typical job	---	13.9±11.91 (0.8-81.0)

Regarding individual job physical exposure variables, peak force and efforts per minute were predictive of an increased risk of any DUE MSD (Tables 4.25 and 4.26). In the multivariate model, peak force > 5.0 had a HR = 1.9 (95% CI = 1.15 - 3.15, p =0.013) (Table 4.25). High repetition (> 22 efforts/min) also showed a statistically significant association (p = 0.02) with increased risk of any DUE MSD in multivariate analyses (Table 4.26). The HRs for efforts/min >22 was 1.85 (95% CI = 1.12 – 3.06. There was no evidence of association between typical or worst hand/wrist posture and HR for any DUE MSD.

Table 4.19: Univariate Hazard Ratios for Job Physical Factors and Covariates with p ≤ 0.10 for Any Disorder Eligible Cohort.

Category	**Variable (overall p-value)**	**Categories**	**HR (95% CI)**	**p-value**
Demographic	Age (years)	≤ 38 >38	1.0 2.37 (1.45 – 3.87)	<0.001
	Gender	Male Female	1.0 2.0 (1.24 – 3.21)	0.005
Anthropometric	Body Mass Index (BMI) (kg/m$^{2)}$	<35 ≥35	1.0 1.5 (0.83 – 2.71)	0.180
Medical History	Osteoarthrosis	No Yes	1.0 1.19 (0.52 – 2.74)	0.678
	Diabetes	No Yes	1.0 0.48 (0.07 - 3.46)	0.467
	High Cholesterol	No Yes	1.0 1.58 (0.89 - 2.80)	0.122
Hobbies/ Activities	Gardening	No Yes	1.0 1.36 (0.88 – 2.11)	0.165
	Knitting	No Yes	1.0 0.99 (0.56 – 1.77)	0.980
	Walking	No Yes	1.0 1.13 (0.73 – 1.75))	0.576
	Baseball	No Yes	0.66 (0.21 – 2.09)	0.481
	Swimming	No Yes	1.07 (0.47 – 2.45)	0.877
	Maintenance Work	No Yes	0.57 (0.32 – 1.01)	0.055

*Distal Upper Extremity (DUE) Musculoskeletal Disorders (MSDs)

Table 4.19 continued: Univariate Hazard Ratios for Job Physical Factors and Covariates with p ≤ 0.10 for Any Disorder Eligible Cohort.

Category	Variable (overall p-value)	Categories	HR (95% CI)	p-value
Psychosocial	Job Satisfaction (p = 0.536)	Very Satisfied Satisfied Neither/Nor Dissatisfied / Very Dissatisfied	1.0 1.43 (0.81 – 2.52) 1.12 (0.56 – 2.25) 1.79 (0.52 – 6.14)	 0.217 0.741 0.357
	Mentally Exhausted (p = 0.022)	Never Seldom Often/Always	1.0 1.99 (1.15 – 3.43) 2.08 (1.08 – 3.99)	 0.014 0.029
	General Health Compared to Others (p = 0.628)	Somewhat/Much Better The Same Somewhat/Much Worse	1.0 1.15 (0.73 – 1.83) 1.39 (0.69 – 2.80)	 0.543 0.356
	Felt Depressed (p=0.075)	Never Seldom Often/Always	1.0 1.11 (0.65 – 1.89) 2.0 (1.07 – 3.75)	 0.702 0.031
Biomechanical Stressors (Typical Exposure)	Peak Force (Worker, Borg CR-10 scale))	≤ 5 > 5	1.0 2.0 (1.21 – 3.31)	 0.007
	Typical Force (Worker, Borg CR-10 scale)	≤ 3 > 3	1.0 1.77 (1.09 – 2.87)	 0.020
	Efforts per Minute	≤ 22 > 22	1.0 2.21 (1.39 – 3.52)	 <0.001
	Efforts per Minute (p = 0.002)	≤ 22 > 22 to ≤35 > 35	1.0 2.04 (1.21 – 3.44) 2.47 (1.42 – 4.27)	 0.008 0.001
	Worst Hand/Wrist Posture (SI Rating)	Very Good, Good, Fair Bad, Very Bad	1.0 0.68 (0.44 – 1.07)	 0.093
	Typical Hand/Wrist Posture (SI Rating)	Very Good, Good, Fair Bad, Very Bad	1.0 0.74 (0.42 – 1.32)	 0.310

*Distal Upper Extremity (DUE) Musculoskeletal Disorders (MSDs)

Table 4.19 continued: Univariate Hazard Ratios for Job Physical Factors and Covariates with p ≤ 0.10 for Any Disorder Eligible Cohort.

Category	Variable (overall p-value)	Categories	HR (95% CI)	p-value
Biomechanical Stressors (Typical Exposure)	Hand Activity Level (HAL) Rating	≤ 5 > 5	1.0 1.35 (0.87 – 2.10)	0.179
	Threshold Limit Value (TLV) for HAL (p = 0.808)	< Action Limit (AL) ≥AL - < TLV ≥TLV	1.0 0.89 (0.50-1.57) 1.04 (0.58 – 1.87)	0.679 0.900
	Threshold Limit Value (TLV) for HAL (2-Category Model)	TLV Raised to 0.87	1.0 2.06 (1.33 – 3.19)	0.001
	Strain Index Score (Analyst Overall Force rating)	≤ 8 > 8	1.0 1.66 (1.02 – 2.71)	0.043
	Strain Index Score (Worker Peak Force rating)	≤ 36 > 36	1.0 2.55 (1.66 – 3.94)	<0.001
	Strain Index Score (Worker Peak Force rating) (<0.001)	≤ 7 > 7 to ≤ 36 > 36	1.0 1.43 (0.51 – 4.02) 3.51 (1.26 – 9.81)	0.496 0.017

*Distal Upper Extremity (DUE) Musculoskeletal Disorders (MSDs)

Table 4.20: Multivariate Model for Predicting Incident Cases of Any DUE Musculoskeletal Disorder with Two Categories of Strain Index Scores Calculated Using Analyst Overall Force Rating.

Variable	Category	Hazard Ratio	95% C.I.	p-Value
Strain Index Score	≤ 8 > 8	1.0 1.38	0.84 – 2.29	0.209
Covariates				
Age (years)	≤ 38 > 38	1.0 2.19	1.33 – 3.58	0.002
Gender	Male Female	1.0 1.74	1.07 – 2.84	0.027

Table 4.21: Multivariate Model for Predicting Incident Cases of Any DUE Musculoskeletal Disorder with Three Categories of Strain Index Scores Calculated using Worker Peak Force Exertion Rating.

Variable	Category	Hazard Ratio	95% C.I.	p-Value
Strain Index Score (p = 0.004)	≤ 7	1.0		
	> 7 to ≤ 36	1.41	0.50 – 3.97	0.511
	>36	2.88	1.02 – 8.09	0.046
Covariates				
Age (years)	≤ 38	1.0		
	> 38	1.97	1.20 – 3.26	0.008
Gender	Male	1.0		
	Female	1.63	1.00 – 2.65	0.049

Table 4.22: Multivariate Model for Predicting Incident Cases of Any DUE Musculoskeletal Disorder with Two Categories of Strain Index Scores Calculated using Worker Peak Force Exertion Rating.

Variable	Category	Hazard Ratio	95% C.I.	p-Value
Strain Index Score	≤ 36	1.0		
	>36	2.11	1.35 – 3.30	0.001
Covariates				
Age (years)	≤ 38	1.0		
	> 38	1.98	1.20 – 3.26	0.008
Gender	Male	1.0		
	Female	1.63	1.00 – 2.66	0.048

Table 4.23 Multivariate Model for Predicting Incident Cases of Any DUE Musculoskeletal Disorder with the Threshold Limit Value for Hand Activity Level (TLV for HAL) using Published TLV Limits

Variable	Category	Hazard Ratio	95% C.I.	p-Value
TLV for HAL (p = 0.471)	< Action Limit (AL)	1.0		
	≥AL - < TLV	1.07	0.52 - 2.18	0.863
	≥TLV	1.38	0.74 – 2.58	0.313
Covariates				
Age (years)	≤ 38	1.0		
	> 38	2.23	1.37 – 3.66	0.001
Gender	Male	1.0		
	Female	1.73	1.06 – 2.83	0.03

Table 4.24: Multivariate Model for Predicting Incident Cases of Any DUE Musculoskeletal Disorder with the Threshold Limit Value for Hand Activity Level (TLV for HAL) using Two Categories for TLV for HAL and Increasing the TLV Above Published Criteria to 0.87*

Variable	Category	Hazard Ratio	95% C.I.	p-Value
TLV for HAL *2 category model, TLV raised to 0.87 from 0.78*	≤ 0.87	1.0		
	> 0.87	1.73	1.10 – 2.71	0.017
Covariates				
Age (years)	≤ 38	1.0		
	> 38	2.16	1.32 – 3.54	0.002
Gender	Male	1.0		
	Female	1.64	1.01 – 2.68	0.048

*The TLV for HAL as published did not provide a measure for statistically significant increased risk of ANY DUE MSD. When the TLV was increased from 0.78 to 0.84, data became statistically significant.

Table 4.25: Multivariate Model for Predicting Incident Cases of Any DUE Musculoskeletal Disorder with Worker Peak Force Rating

Variable	Category	Hazard Ratio	95% C.I.	p-Value
Worker Peak Force Rating on Borg CR-10 Scale (Typical Job)	≤ 5.0 > 5.0	1.0 1.90	 1.15 – 3.15	 0.013
Covariates				
Age (years)	≤ 38 > 38	1.0 2.23	 1.36 – 3.64	 0.001
Gender	Male Female	1.0 1.81	 1.12 – 2.92	 0.015

Table 4.26: Multivariate Model for Predicting Incident Cases of Any DUE Musculoskeletal Disorder with Exertions per Minute

Variable	Category	Hazard Ratio	95% C.I.	p-Value
Exertions/min (Typical Job)	≤ 22 > 22	1.0 1.85	 1.12 – 3.06	 0.016
Covariates				
Age (years)	≤ 38 > 38	1.0 2.2	 1.34 – 3.60	 0.002
Gender	Male Female	1.0 1.46	 0.87 – 2.45	 0.151

5. Discussions

5.1. Discussions: Carpal Tunnel Syndrome

These results suggest that CTS has a complex, multifactorial etiology in a manufacturing setting. These factors include: (i) job physical factors (peak force and SI score), (ii) worker demographics (obesity), (iii) co-morbidity (inflammatory arthritis and other DUE MSDs), (iv) psychosocial factors (feeling mentally exhausted), and (v) worker hobbies (gardening). Of these variables, the job physical factors as assessed by the SI most strongly predicted risk, with HRs up to 9.1. The TLV for HAL was not predictive as originally constructed but was predictive after simplifying and raising the TLV cut point. These results strongly suggest force is the most important job physical factor for CTS. These data also suggest cases of CTS occurring among high exposure groups in manufacturing workers are most likely to be due to job physical factors. Yet, they also suggest population-based controls to reduce risk of CTS will require multi-faceted approaches.

While many prior studies have reported associations with job physical factors, most studies either used retrospective methods, had no objective CTS measurement, and/or did not adjust for at least some of these covariates (Silverstein et al. 1987, Chiang et al. 1990, 1993, Osorio 1994, Radecki 1994, Bernard, 1997, Roquelaure et al. 1997, Franzblau et al. 2005, Bovenzi et al. 2005, Silverstein et al. 2006, Violente et al., 2007). This study addressed many of these weaknesses found in prior studies through use of prospective methods, careful measurement of job physical factors, determination of disease status at baseline, reliance on nerve conduction studies, measured body mass indices and frequent follow-up of the cohort. It is possible that through these detailed methods, relying primarily on objective measurements, the strengths of associations of this study are greater than those reported in prior studies.

5.1.1. Exposure Distribution

To avoid selection bias no efforts were made to include or exclude workers based on level of physical exposure. This study population appears to have an over-representation of workers in the high exposure group as measured by TLV for HAL and the Strain Index (44.3% workers below TLV and 55.7% above TLV or 20.5% workers < AL, 23.8% between AL and TLV and 55.7% > TLV; 28.2% workers SI ≤ 6.0, 27.0% with SI > 6.0 and ≤ 12.0%, 19.3% with SI > 12.0 and ≤ 18.0, 4.7% with SI > 18.0 and ≤ 24.0 and 20.8% with SI > 24.0). Other studies have also reported unequal percentages of workers in low, medium and high exposure groups (Werner et al. 2005a,b, Violante et al. 2007). As distributions of the predictor variables (TLV for HAL and SI score) do not affect the validity of the Cox regression results unless the distribution is extremely skewed (Cox 1972, Miller 1998), we do not believe that the distribution of workers in different physical exposure groups in this study affects the generalizability of our results to other manufacturing and assembly operations. Confidence intervals for practically all categories were fairly narrow indicating there were no problems with model convergence.

5.1.2. Exposure Assessment

Job physical exposures were assessed from typical jobs (i.e., a jobs performed for the largest duration of work shift when a worker rotated to two or more jobs) and peak exposure jobs. These methodologies ignored physical exposure from other jobs performed by some of the workers during an entire work shift. Time-weighted physical exposure for the Strain Index and TLV for HAL were considered inappropriate, as this tends to dilute physical exposure (Garg and Kapellusch 2009a,b). None of these summary measures are expected to characterize job exposure completely and may result in exposure misclassification (Garg and Kapellusch 2009a). For example, the time-weighted average approach will probably underestimate overall exposure, while the peak exposure approach may overestimate the overall exposure (Dempsey 1999, Garg and Kapellusch 2009a,b). Thus there is a need to develop a methodology, such as Cumulative Strain Index (Garg and Kapellusch 2009a) that would integrate stresses to distal upper extremity over an entire work shift. Cumulative exposure (integrated exposure) should include stress to the worker from all different tasks that the worker performs during a work shift.

5.1.3. The Strain Index

In multivariate analyses, the relationships between the SI scores and increased risk for CTS were substantially strengthened as compared to univariate analyses (e.g., from HR=4.9 to HR=9.1) that may represent effects of confounding. There also was a relatively reduced hazard ratio in the highest group (SI>24) which might be due to selection biases with workers in the most physically demanding jobs migrating out of those jobs prior to development of disease, or other factors.

An increased hazard ratio was found for a SI score greater than 6.0. Moore and Garg (1995) previously proposed a designation of “hazardous” for a SI score greater than 5.0 based on their data from a pork processing plant. Subsequently, Rucker and Moore (2001) suggested a SI score of greater than 9.0 for classifying “hazardous” manufacturing jobs. Based on an analysis of pooled data from three different studies (pork processing, turkey processing and manufacturing), Moore et al. (2006) more recently suggested that a SI score greater than 6.1 best distinguished between safe and hazardous jobs. Surprisingly, the cut point of 6.0 found in this study is nearly identical to the score of 6.1 proposed by Moore et al. (2006) for DUE disorders in aggregate.

There are only a few studies that have examined relationships between the Strain Index and risk of CTS (Bovenzi et al. 2005, Silverstein et al. 2006), and they reported an association between the SI score and prevalence or incidence of CTS. This study appears to have validated the SI.

5.1.4. TLV for HAL

This study was unable to validate the TLV for HAL. However, a simple, two-category model for the TLV for HAL with the TLV value raised from 0.78 to 0.84 (a modest 7.7% increase in the published TLV value) showed evidence of increased risk of CTS. These results are generally consistent with prior reports. While Violente et al. (2007) showed that the TLV for HAL was associated with an increased risk of CTS, three other studies found weak predictive abilities or trends toward predictive ability (Franzblau et al. 2005, Gell et al. 2005 and Werner et al. 2005a). It should be noted that none of the studies reported in the literature have used any other values for AL or TLV other than those prescribed by the ACGIH (2002). Thus, a direct comparison of results with the modified TLV for HAL is not possible. If the results of this study are replicated, it is suggested there be a consideration to reconfigure the TLV for HAL to show the increased impact of force compared to repetition.

5.1.5. Job Individual Variables

Among different job physical exposure variables, force, repetition and posture have been reported to be associated with increased risk of CTS (Armstrong and Chaffin 1979, Silverstein et al. 1987, Wieslander et al. 1989, Chiang et al. 1990, 1993, de Krom et al. 1990, Tanaka et al. 1995, 2001, Roquelaure et al. 1997, Leclerc et al. 1998, 2001, Thomsen et al. 2002, Werner et al. 2005ab, Melchior et al. 2006). Out of these three variables, this study found evidence of increased risk of CTS with peak force and high rates of efforts per minute (high repetition, peak exposure only), but not posture both in univariate and multivariate analyses. It should be noted that our definition of efforts per minute included all efforts irrespective of the force required to perform the job. This included near negligible force exertions that were assigned a force value of zero on the Borg CR-10 scale as well as forceful exertions. This might explain large values of efforts/min observed in this study. A comparison of HRs in univariate analyses shows that these individual job physical factors (peak force for typical exposure and efforts/min for peak exposure) performed better than the 2-category Strain Index model or the revised TLV for HAL. This would suggest that job physical exposure hazard could be classified using worker peak force rating alone rather than a more complex model such as the Strain Index. However, in general this may not be true. First, it should be noted that among all models tested the five-category SI model performed the best. Second, the SI scores calculated using worker force rating (in place of analyst overall force rating) performed better than the worker peak force rating alone. Since the Strain Index score is based on multiplicative effects (multipliers) of force, repetition, posture and duration of force exertion, etc., this implies interactions between different job physical exposure variables are important. Hand/wrist posture while statistically not significant had a HR of less than 1.0, implying that bad postures were protective. This might have negatively affected the relationship between SI score and increased risk of CTS. This further stresses the need for developing job analysis methods such as Composite Strain Index (Garg and Kapellusch 2009a) that consider combinations of force, posture and repetition for each exertion rather than overall values of these variables for the entire task. Lastly, the mean efforts/min in this study was 26.6. The SI methodology caps the effort multiplier at 20 efforts/min. Thus, jobs with very high efforts/min (>> 20) might not have received appropriately high SI scores. The relationship between efforts/min and SI score may need to be further investigated.

5.1.6. Worker Demographics

Age, gender, BMI and pregnancy have been reported to be associated with increased risk of CTS (Cannon et al 1981, Dieck et al. 1985, Wieslander et al. 1989, Vessey et al. 1990, de Krom et al. 1990, McCormack et al. 1990, Franklin et al. 1991, Morgenstern et al. 1991, Florack et al. 1992, Nathan et al. 1992a,b, Werner et al 1994, English et al. 1995, Tanaka et al. 1995, 2001, Rocquelaure et al. 1997, Stallings et al 1997, Leclerc et al 1998, 2001, Kouyouymdjian et al. 2002, Anton et al. 2002, Boz et al. 2004, Werner et al. 2005a, Moghtaderi et al. 2005, Gell et al. 2005). This study found evidence for BMI. Both age and female gender were significant in univariate, but not multivariate analyses. This study was likely underpowered to determine risk of CTS from pregnancy as only 2/244 (0.82%) females were pregnant at baseline and 16/244 (6.6%) became pregnant during follow up.

5.1.7. Past Medical History

This study found that baseline prevalence of inflammatory arthritis (including rheumatoid arthritis) was associated with an elevated risk for CTS. Only a few studies have investigated the role of rheumatoid arthritis in the development of CTS (de Krom et al. 1990, Stevens et al. 1992, Gell et al. 2005, Werner et al. 2005a). Out of these four studies Stevens et al. (1992) found an association between rheumatoid arthritis and prevalence of CTS. The other studies found no association. However, these studies might have been underpowered as people with rheumatoid arthritis may avoid repetitive work in manufacturing environments. This study found no association between diabetes mellitus and incident cases of CTS. This may be due to insufficient statistical power.

5.1.8. Co-morbidity

Aggregate DUE MSDs were associated with an increased risk of CTS. Others have reported increased risk of CTS from any MSD (Ferry et al 2000), upper extremity tendinitis (Gell et al. 2005), and wrist, hand and finger tendinitis (Werner 2005a). However, Leclerc et al. (2001) found no association between baseline aggregate disorders and increased risk of CTS. Moore (1992) reported that work-related CTS is almost always associated with other MSDs, infrequently occurs without co-morbidity, and may be a complication of other specific DUE MSDs (Moore 1992). In this study, 51% of CTS cases had one or more DUE MSDs compared to 26% of non-CTS cases (2-fold increased risk). Thus, this study supports the theory that DUE MSDs are associated with the development of CTS.

It is not clear what the mechanism of action is and anatomically how deQuervain's, trigger thumb and extensor wrist tendinoses, etc. contribute to CTS etiology. Nevertheless, association between various muscle-tendon disorders and risk of CTS has been a consistent finding in several studies (Ferry et al. 2000, Gell et al. 2005, Werner et al 2005). Possible explanations include: worker may use compensatory strategies that translate into higher loads on the hand/wrist and/or genetic predisposition to soft tissue/connective tissue failure (Ferry et al. 2000, Gell et al. 2005, Werner et al. 2005a). With regard to genetic predisposition, our study did find an association between family history of CTS and risk of developing CTS in univariate analyses. This suggests that there might be a genetic link to soft-tissue disorders in general. Another possibility is that since most biomechanical risk factors for CTS and soft tissue disorders coincide, it may simply take longer for CTS to develop, causing other DUE soft tissue disorders to appear first.

5.1.9. Psychosocial Factors

Only a few studies have assessed psychosocial factors and no consistent associations have been identified (Bernard 1997, Nordstrom 1997, Werner 1998, Leclerc 2001, Roquelaure 2001, Reading 2003). This study found evidence of association between feelings of mental exhaustion after work and increased HRs for CTS. While mental stress has been associated with an increased prevalence of trapezius myalgia, lateral humeral epicondylitis and radial tunnel syndrome (Dimberg et al. 1989), there are no studies on mental exhaustion after work and CTS. However, mental stress can lead to stress induced muscle activity, and continuously increased muscular activity can lead to fatigue and thus eventually cause musculoskeletal complaints (Rissen et al. 2000, Bloemsaat et al. 2005). It is well established that mental stress causes an increase in blood pressure but its association with CTS needs to be further investigated. Mental fatigue also leads to higher perception of effort during exercise and limits exercise tolerance (Marcora et al. 2009). It could be that in this study increased mental fatigue is appearing as a form of “perceived job stress.” Based on a review of psychosocial factors and DUE MSDs (and not necessarily CTS) Feuerstein et al. (2004) concluded that high perceived job stress showed the strongest evidence of contributing to upper extremity symptoms. Still, the mechanisms for how mental exhaustion after work causes CTS are unknown and this relationship needs to be verified in future studies.

5.1.10. Strengths and Weaknesses of the Study

This study’s strengths include: prospective methods, enrollments of large numbers of workers from diverse employers performing different work, assessments and measurements of numerous potential confounders, use of computerized structured interviews, reliance on NCSs at baseline and follow-ups, exclusions of pre-existing or prevalent cases, detailed quantification of job physical factors, blinding of team members, monthly health status follow-ups, quarterly job physical assessment follow-ups of the cohort and moderately long follow-up of the cohort. These methods appear likely to have resulted in stronger measures of effect than many prior studies, including a finding of a dose-response relationship between job physical factors and CTS. Study limitations include that workers were primarily from manufacturing environments, thus the results might not be directly applicable in other environments, particularly to office settings. Some of the commonly reported risk factors such as diabetes, thyroid disease and pregnancy were likely inadequately assessed due to limited sample size of affected, eligible individuals, as study enrollments intentionally attempted to target one-third high, medium and low job physical demands for adequate powering of job physical demands.

5.2. Discussions: Lateral Epicondylitis

These results suggest that lateral epicondylitis has a complex, multifactorial etiology in a manufacturing setting. These factors include: (i) job physical factors (SI score, TLV for HAL), (ii) worker demographics (age >35 years), (iii) physical activities outside of work (playing baseball), and (iv) psychosocial factors (feelings of depression). Of these variables, the job physical factors as assessed by the SI showed a modest risk, with HR of 1.8 ($p = 0.04$). The TLV for HAL was inconsistent (reduced risk for exposure between AL and TLV and increased risk above TLV) as originally constructed but was predictive after simplifying and raising the TLV cut point. Results also suggest force and repetition are the most important job physical factors for lateral epicondylitis. These data also suggest cases of lateral epicondylitis occurring among high exposure groups in manufacturing workers are likely to be due to job physical factors. Yet, they also suggest population-based controls to reduce risk of lateral epicondylitis will require multi-faceted approaches.

While many prior studies reported associations with job physical factors, most studies used retrospective methods, had no objective lateral epicondylitis assesment, and/or did not adjust for at least some of these covariates (Bernard 1997, Haahr and Andersen 2003, Moore and Garg 1994, Franzblau et al. 2005, Werner et al. 2005, Shiri et al.2006, van Rijn et al. 2009). This study addressed many weaknesses of prior studies through use of prospective methods, careful measurement of job physical factors, determination of disease status at baseline, measured body mass indices and frequent follow-up of the cohort

5.2.1. Exposure Assessment

Job physical exposures were assessed from typical jobs (i.e., the job performed for the largest duration of work shift when a worker rotated to two or more jobs) and peak exposure jobs. These methodologies ignored physical exposure from other jobs performed by some of the workers during an entire work shift. Time-weighted physical exposure for the Strain Index and TLV for HAL were considered inappropriate, as this tends to dilute physical exposure (Garg and Kapellusch 2009a,b). None of these summary measures are expected to characterize job exposure completely and may result in exposure misclassification (Garg and Kapellusch 2009a). For example, the time-weighted average approach will probably underestimate overall exposure, while the peak exposure approach may overestimate the overall exposure (Dempsey 1999, Garg 2006, Garg and Kapellusch 2009a,b). Thus there is a need to develop a methodology, such as Cumulative Strain Index (Garg and Kapellusch 2009a) that would integrate stresses to distal upper extremity over an entire work shift. Cumulative exposure (integrated exposure) should include stress to the worker from all different tasks that the worker performs during a work shift.

5.2.2. The Strain Index

In multivariate analyses, the statistical association between the SI score and increased risk for lateral epicondylitis was strengthened as compared to univariate analysis (e.g., from $p = 0.09$ to $p = 0.04$) and that may represent effects of confounding.

An increased hazard ratio was found for a SI greater than 8.0. Moore and Garg (1995) previously proposed a designation of “hazardous” for a SI greater than 5.0 based on their data from a pork processing plant. Subsequently, Rucker and Moore (2001) suggested a SI score of greater than 9.0 for classifying “hazardous” manufacturing jobs. Based on an analysis of pooled data from three different studies (pork processing, turkey processing and manufacturing), Moore et al. (2006) more recently suggested that a SI greater than 6.1 best distinguished between safe and hazardous jobs. The cut point of 8.0 found in this study is within the range of cut points suggested by previous studies for all DUE MDSs combined together (aggregate disorders).

There has been only one study that has reported relationship between the Strain Index and risk of lateral epicondylitis (Cited in Bernard et al. 1997, page 4-7). This current study appears to have validated the SI.

5.2.3. TLV for HAL

The TLV for HAL showed overall statistical significance but the results were inconsistent (reduced risk for exposure between AL and TLV and increased risk above TLV). However, a simple, two- category model for the TLV for HAL with the TLV value raised from 0.78 to 0.87 (an 11.5% increase in the published TLV value) showed evidence of increased risk of lateral epicondylitis. These results are generally consistent with prior reports. While Franzblau et al. (2005) reported tendonitis in the elbow/forearm showed a highly significant linear trend with increasing ergonomic exposures, Werner et al. (2005) found no association between the TLV for HAL and the increased risk of lateral epicondylitis. It should be noted that none of the studies reported in the literature have used any other values for AL or TLV other than those prescribed by the ACGIH (2002). Thus, a direct comparison of results with the modified TLV for HAL is not possible. If the results of this study are replicated, it is suggested there be a consideration to reconfigure the TLV for HAL to show the increased impact of force compared to repetition.

5.2.4. Job Individual Variables

Individual job physical variables, force, repetition or posture, were not associated with an increased risk for lateral epicondylitis ($p \geq 0.117$). Previous studies have reported that combinations of high force and high repetition, high force and extreme posture and high repetition and extreme posture are associated with increased risk (Bernard 1997, Haahr and Andersen 2003, Shiri et al. 2006). Regarding individual contribution of these three variables, previous studies suggest that force might be more important than repetition and posture (Moore and Garg 1994, Bernard 1997, Shiri et al. 2006).

The results of this study as well as previous studies suggest that there is interaction between different job physical factors such as force, repetition and posture. This stresses the need for developing job analysis methods such as Composite Strain Index (Garg and Kapellusch 2009a) that consider combinations of force, posture and repetition for each exertion rather than overall values of these variables for the entire job. Lastly, the mean efforts/min in this study was 25.8±14.88. The SI methodology caps the effort multiplier at 20 efforts/min. Thus, jobs with very high efforts/min (>> 20) might not have received appropriately high SI scores. The relationship between efforts/min and SI score may need to be further investigated.

5.2.5. Worker Demographics

Age has been reported to be associated with increased risk of lateral epicondylitis (Roto and Kivi 1984, Dimberg 1987, Viikari-Juntura et al. 1991, Ono et al. 1998, Werner et al 2005). This study found evidence for age. Similarly, female gender has been suggested as a possible risk factor (McCormack et al. 1990, Viikari-Juntura et al. 1991, Ono et al. 1998,). Female gender was not significant either in univariate or multivariate analyses.

5.2.6. Past Medical History

Only a few studies have investigated the role of past medical history in the development of lateral epicondylitis. None of the past medical history assessments studied was associated with an elevated risk for lateral epicondylitis. Our results are consistent with those reported by Werner et al. (2005).

5.2.7. Hobbies and Physical Activities

What role hobbies and outside work physical activities play for elevated risk of lateral epicondylitis has been rarely studied (Dimberg et al. 1989). Out of many hobbies and physical activities studied, only playing baseball was associated with an increased risk of lateral epicondylitis. Baseball does require forceful exertions. But it is not clear why other hobbies and physical activities that also require forceful exertions such as weight lifting, carpentry work, maintenance work, etc were not associated with an increased risk of lateral epicondylitis.

5.2.8. Psychosocial Factors

Psychosocial factors have been rarely studied in relation to lateral epicondylitis and no consistent associations have been identified (Ono et al. 1998, Haahr and Andersen 2003, Wener et al. 2005). This study found evidence that feelings of depression are associated with increased risk for lateral epicondylitis; however, no other psychosocial variables were significant in the multivariate models. While there are several studies on how DUE MSDs affect depression, little information is available regarding depression as a risk factor for lateral epicondylitis. Depression was addressed in this study by asking the workers the following question, "How often do you feel down, blue or depressed?" This may not imply clinical depression. Given four choices for this question (never, seldom, often and always), more than 26% of workers responded "never ", 49% "seldom", 17% often and 2% always. There was no significant difference between hazard ratios for seldom (HR =2.03) and always/often (HR = 2.29) responses. Depression has been shown to be correlated to Musculoskeltal disorders (Antonopoulou et al. 2009) and lateral epicondylitis in particular (Leclerc et al. 2001). Job satisfaction while significant in univariate analysis, dropped out of the multivariate analyses. Our findings on job satisfaction (or dissatisfaction) and some other psychosocial variables are consistent with those reported in the past (Werner et al. 2005).

5.2.9. Strengths and Weaknesses of the Study

This study's strengths include: prospective methods, enrollments of large numbers of workers from diverse employers performing different work, assessments and measurements of numerous potential confounders, use of computerized structured interviews, exclusions of pre-existing or prevalent cases, detailed quantification of job physical factors, blinding of team members, monthly health status follow-ups, quarterly job physical assessment follow-ups of the cohort and moderately long follow-up of the cohort. These methods appear likely to have resulted in stronger measures of effect than many prior studies, including a finding of a relationship between job physical factors and lateral epicondylitis. Study limitations include that workers were primarily from manufacturing environments, thus the results might not be directly applicable in other environments, particularly to office settings.

5.3. Discussions: Any DUE MSD

First lifetime occurrence of any DUE MSD was analyzed in a virgin cohort, i.e., workers who had no prior history of any DUE MSD at the time of enrollment. There are no studies in the literature that have used a virgin cohort to study risk factors of DUE MSDs in manufacturing settings. The very high lifetime prevalence of DUE MSDs (56.5%) observed in this study shows that many workers suffer from one or more DUE MSDs.

Results from this study suggest that risk factors for DUE MSDs include: (i) job physical factors (high force, high repetition and SI score) and (ii) worker demographics (age and female gender). Job physical factors as assessed by the SI and calculated using worker peak force rating most strongly predicted risk, with a hazard ratio of 2.88. The TLV for HAL was not predictive as originally constructed but was predictive after simplifying to a two-category model and raising the TLV cut point. These results strongly suggest force is the most important job physical factor for development of DUE MSDs. These data also suggest cases of DUE MSDs occurring among high exposure groups in manufacturing workers are most likely to be due to job physical factors.

While many prior studies reported associations with job physical factors, most studies either used retrospective methods, had no objective DUE MSD measurement, and/or did not adjust for at least some of these covariates (Silverstein et al. 1987, Chiang et al. 1990, 1993, Osorio 1994, Radecki 1994, Bernard, 1997, Roquelaure et al. 1997, Franzblau et al. 2005, Bovenzi et al. 2005, Silverstein et al. 2006, Violente et al., 2007, Fan et al 2009). This study addressed many weaknesses found in prior studies through use of prospective methods, careful measurement of job physical factors, determination of disease status at baseline, reliance on nerve conduction studies and physical examinations, measured body mass indices and frequent follow-up of the cohort. It is possible that through these detailed methods, relying primarily on objective measurements, the strengths of associations are greater than those reported in some of the prior studies.

5.3.1. Exposure Distribution

To avoid selection bias no efforts were made to include or exclude workers based on level of physical exposure. This study population appears to have an over-representation of workers in the high exposure group as measured by TLV for HAL and the Strain Index. Other studies have also reported unequal percentages of workers in low, medium and high exposure groups (Werner et al. 2005a,b, Violante et al. 2007). As distributions of the predictor variables (TLV for HAL and SI score) do not affect the validity of the Cox regression results unless the distribution is extremely skewed (Cox 1972, Miller 1998), we do not believe that the distribution of workers in different physical exposure groups in this study affects the generalizability of our results to other manufacturing and assembly operations. Confidence intervals for practically all categories were fairly narrow indicating there were no problems with model convergence.

5.3.1.1. Exposure Assessment

Job physical exposures were assessed from typical jobs (i.e., the job performed for the largest duration of work shift when a worker rotated to two or more jobs) and peak exposure jobs. These methodologies ignored physical exposure from other jobs performed by some of the workers during an entire work shift. Time-weighted physical exposure for the Strain Index and TLV for HAL were considered inappropriate, as this tends to dilute physical exposure (Garg and Kapellusch 2009a,b). None of these summary measures are expected to characterize job exposure completely and may result in exposure misclassification (Garg and Kapellusch 2009a). For example, the time-weighted average approach will probably underestimate overall exposure, while the peak exposure approach may overestimate the overall exposure (Dempsey 1999, Garg 2006, Garg and Kapellusch 2009a,b). Thus there is a need to develop a methodology, such as Cumulative Strain Index (Garg and Kapellusch 2009a) that would integrate stresses to distal upper extremity over an entire work shift. Cumulative exposure (integrated exposure) should include stress to the worker from all different tasks that the worker performs during a work shift.

5.3.2. The Strain Index

While SI score was statistically significant in univariate analysis ($p = 0.04$), it was not predictive in the adjusted model. The univariate results are consistent with those reported by Moore and Garg (1995), Rucker and Moore (2001) and Moore et al. (2006). Studies by Moore reported the relationship between the SI and DUE MSDs without adjustment for any covariates.
The SI scores calculated using worker peak force rating in place of analyst's overall force rating were predictive ($p = 0.004$) of any DUE MSD and showed a trend with almost 3-fold increase for SI score > 36. There are issues with assigning analyst's overall force rating for those jobs where force level changes considerably during a job cycle. It is difficult to accurately estimate force requirements of a job based on either field observations and/or videotapes. It is possible that analysts may have underestimated force requirements significantly. Use of worker peak force rating may be a another option to calculate SI scores, and it is easier to obtain than estimating

analyst's overall force rating. This issue needs to be further explored and it will impact the cut off limit for "safe" and "hazardous" jobs.

5.3.3. TLV for HAL

This study was unable to validate the TLV for HAL as published. However, a simple, two-category model for the TLV for HAL with the TLV value raised from 0.78 to 0.87 (a 11.5% increase in the published TLV value) showed evidence of increased risk of any DUE MSD. These results are generally consistent with prior reports for CTS and lateral epicondylitis. While a few studies have shown a relationship between TLV for HAL and CTS and lateral epicondylitis (Franzblau et al. 2005, Violente et al. 2007), other studies found weak predictive abilities or trends toward predictive ability (Franzblau et al. 2005, Gell et al. 2005 and Werner et al. 2005a,b). It should be noted that none of the studies reported in the literature have used any other values for AL or TLV other than those prescribed by the ACGIH (2002). Thus, a direct comparison of results with the modified TLV for HAL is not possible. If the results of this study are replicated, it is suggested there may be a consideration to reconfigure the TLV for HAL to show the increased impact of force compared to repetition.

5.3.4. Job Individual Variables

Most studies have investigated relationships between job physical exposure variables and either CTS or lateral epicondylitis rather than DUE MSDs in general. Among different job physical exposure variables, force, repetition and posture have been most often associated with increased risk of CTS, lateral epicondylitis, or DUE MSDs (Armstrong et al. 1987, Silverstein et al. 1987, Wieslander et al. 1989, Chiang et al. 1990, 1993, de Krom et al. 1990, Loslever and Ranaivosoa 1993, Moore and Garg 1994, Osorio et al. 1994, Tanaka et al. 1995, 2001, Bernard 1997, Roquelaure et al. 1997, 2001, Leclerc et al. 1998, 2001, Moore et al. 2001, Katz and Simmons 2002, Thomsen et al. 2002, Haahr and Andersen 2003, Werner et al. 2005ab, Melchior et al. 2006, Shiri et al. 2006, Bonfiglioli et al. 2007, Gardner et al 2008, Spielholz et al 2008, Silverstein et al. 2010). Out of these three variables, this study found evidence of increased risk of any DUE MSD with peak force and high rates of efforts per minute (high repetition), but not posture in adjusted models. Moore and Garg (1994) reported that DUE MSDs were related to force and inversely related to % recovery time. Andersen et al. (2007) and Fernandes et al (2010) reported that highly repetitive work was predictive of arm pain.

While, in general, the literature indicates a strong association between repetition, force, and vibration and DUE MSDs (Bernard 1997, National Research Council and Institute of Medicine 2001), it appears that jobs that require both high force and high repetition have greater association with DUE MSDs than those jobs that require exposure to high force or high repetition alone (Armstrong et al. 1987, Silverstein et al. 1987, Chiang et al. 1993, Osorio et al. 1994, Moore et al. 2001, Melchior et al. 2006).

A comparison of hazard ratios in multivariate analyses shows that the Strain Index calculated using worker peak force rating performed better than individual job physical factors (peak force and efforts/min. This suggests that when adjusted for relevant covariates, there is an interaction between different job physical factors such as force, repetition, posture, and duration of exertion. The Strain Index score is based on multiplicative effects (multipliers) of force, repetition, posture and duration of force exertion, etc.; this implies interactions between different job physical exposure variables are important. Surprisingly, hand/wrist posture had a hazard ratio of less than

1.0 (though not statistically significant), implying that bad postures were protective. This might have negatively affected the relationship between SI score and increased risk of any DUE MSD. This further stresses the need for developing job analysis methods such as Composite Strain Index (Garg and Kapellusch 2009a) that consider combinations of force, posture and repetition for each exertion rather than overall values of these variables for the entire job. Lastly, the mean efforts/min in this study was 25.9. The SI methodology caps the effort multiplier at 20 efforts/min. Thus, jobs with very high efforts/min (>> 20) might not have received appropriately high SI scores. The relationship between efforts/min and SI score may need to be further investigated.

5.3.5. Worker Demographics

Age, female gender and BMI have been reported to be associated with increased risk of CTS, lateral epicondylitis, and DUE MSDs (Cannon et al 1981, Roto and Kivi 1984, Dieck et al. 1985, Dimberg 1987, Wieslander et al. 1989, de Krom et al. 1990, McCormack et al. 1990, Vessey et al. 1990, Franklin et al. 1991, Morgenstern et al. 1991, Viikari-Juntura et al. 1991, Florack et al. 1992, Nathan et al. 1992a,b, Werner et al 1994, English et al. 1995, Tanaka et al. 1995, 2001, Rocquelaure et al. 1997, Stallings et al 1997, Leclerc et al 1998, 2001, Ono et al. 1998, Anton et al. 2002, Kouyouymdjian et al. 2002, Boz et al. 2004, Gell et al. 2005, Moghtaderi et al. 2005, Werner et al. 2005a, Fernandes et al. 2010). This study found evidence for age and female gender. Both age and female gender were significant in univariate as well as multivariate analyses.

5.3.6. Psychosocial Factors, Hobbies and Physical Activities Outside of Work

This study found no evidence that psychosocial factors, hobbies or physical activities outside of work are associated with increased risk of first lifetime occurrence of any DUE MSD. In general the literature suggests that certain psychosocial factors such as perceived stress, high work demands and little control over work might be associated with DUE MSDs (National Research Council and Institute of Medicine 2001, Devereux et al 2002, Bongers et al 2006, Waters et al. 2007). However, Andersen et al. (2007) from a two-year prospective cohort study concluded that psychosocial work place factors were only of marginal importance. Similarly, Harcombe et al. (2010) did not find an association between psychosocial factors and self-reported DUE pain. This study was conducted on a virgin cohort and relied on frequent physical examinations to determine cases. It is possible that the observed differences with other studies may be due to differences in study design. In this regard it should be noted that epidemiological studies on DUE MSDs typically include workers both with and without prior or existing DUE MSDs, often rely on job titles for exposure classification and self-reported measures of symptoms versus physical examination findings. Because of these differences in study design, research results could be very different (Wang et al. 2009).

6. Conclusions

This study suggests a multifactor etiology for CTS in manufacturing settings. These factors include job physical factors, BMI, feelings of mental exhaustion after work, inflammatory arthritis, co-morbidity of other DUE MSDs, and gardening. Of job physical exposure factors, the SI was the strongest factor and data suggest a dose-response relationship. The ACGIH TLV for HAL was predictive only after raising the TLV by 8%. The SI may be the best predictor for risk of CTS, possibly because it both weights force most strongly and relies on interactions between and among several job physical factors.

This study suggests a multifactor etiology for lateral epicondylitis in manufacturing settings. These factors include job physical factors, age >35 years, feelings of depression, and playing baseball. Of job physical exposure factors, both SI and ACGIH TLV for HAL were predictive of lateral epicondylitis, though TLV for HAL as published showed inconsistent results. The ACGIH TLV for HAL performed better after simplifying and raising the TLV by 11.5%. Individual job physical exposure variables did not predict risk of lateral epicondylitis. The results suggest that interaction between job physical variables such as those represented by the SI and the simplified TLV for HAL predict risk of lateral epicondylitis.

This study suggests a multifactor etiology for any DUE MSD in manufacturing settings. These factors include job physical factors (high force, high repetition and SI), age and female gender. Of job physical exposure factors, the SI calculated using worker peak force rating was the strongest factor and data suggest a dose-response relationship. The ACGIH TLV for HAL was predictive only after raising the TLV by 11.5%. The SI may be the best predictor for risk of any DUE MSD, possibly because it both weights force most strongly and relies on interactions between and among several job physical factors.

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Appendix A:

APPENDIX A.1

Initial Classification of Jobs into Low, Medium, and High Exposure

JOB EVALUATION for INITIAL CLASSIFICATION of JOBS INTO LOW, MEDIUM and HIGH EXPOSURE CATEGORIES

Date ______________________ Analyst __________________________

1. Name _____________________ 2. Plant ____________________________

3. Department ________________ 4. Job Title __________________________

5. Sub-Job Title ______________ 6. Shift ____________________________

7. Does worker rotate to another job? � Yes � No

   If Yes, jobs the observed worker rotates to:

   a. Job Title ______________ Department _______________
   ______________________ Hours/Shift __________________

   b. Job Title ______________ Department _______________
   ______________________ Hours/Shift __________________

   c. Job Title ______________ Department _______________
   ______________________ Hours/Shift __________________

   d. Job Title ______________ Department _______________
   ______________________ Hours/Shift __________________

8. Cycle time (O/V)_____________________________________seconds

9. Duration of exposure on this job (O) _____________________hours/day

10. Length of shift (O) _____________________________________hours/day

Force (Borg Rating)	**Number of Exertions per Minute**	**% Duration of Exertion**	**Hand/Wrist Posture Flexion/Extension**
≤ 2 �L	≤ 4 �L	≤ 20% �L	≤ 20º �G
3-4 �M	5-8 �M	21-40% �M	21-40º �F
≥ 5 �H	> 8 �H	> 40% �H	> 40º �P

Table A-1: Combinations of Force, Repetition, % Duration of Exertion and Hand/Wrist Posture to be Used to Initially Classify Jobs into High, Medium and Low Risk Groups.

High Risk				Medium Risk				Low Risk			
F	**R**	**D**	**P**	**F**	**R**	**D**	**P**	**F**	**R**	**D**	**P**
H	L	M	P	H	L	L	P	H	L	L	G
H	L	H	G	H	L	M	G	H	L	L	F
H	L	H	F	H	L	M	F	M	L	L	G
H	L	H	P	H	M	L	G	M	L	L	F
H	M	L	P	H	M	L	F	M	L	L	P
H	M	M	G	M	L	M	P	M	L	M	G
H	M	M	F	M	L	H	G	M	L	M	F
H	M	M	P	M	L	H	F	M	M	L	G
H	M	H	G	M	M	L	P	M	M	L	F
H	M	H	F	M	M	M	G	L	L	L	G
H	M	H	P	M	M	M	F	L	L	L	F
H	H	L	G	M	H	L	G	L	L	L	P
H	H	L	F	M	H	L	F	L	L	M	G
H	H	L	P	M	H	L	P	L	L	M	F
H	H	M	G	M	H	M	G	L	L	M	P
H	H	M	F	M	H	M	F	L	L	H	G
H	H	M	P	M	H	M	P	L	L	H	F
H	H	H	G	L	L	H	P	L	M	L	G
H	H	H	F	L	M	H	G	L	M	L	F
H	H	H	P	L	M	H	F	L	M	L	P
M	L	H	P	L	M	H	P	L	M	M	G
M	M	M	P	L	H	L	P	L	M	M	F
M	M	H	G	L	H	M	G	L	M	M	P
M	M	H	F	L	H	M	F	L	H	L	G
M	M	H	P	L	H	M	P	L	H	L	F
M	H	H	G	L	H	H	G				
M	H	H	F	L	H	H	F				
M	H	H	P								
L	H	H	P								

F = Force (H = high, M = medium, L = low)
R = Repetition (H = high, M = medium, L = low)
D = % Duration of Exertion (H = high, M = medium, L = low)
P = Hand/Wrist Posture (G = good, F = Fair, P = poor)

APPENDIX A.2

Field Data Collection Instructions

Position / Worker Specific Data Form Instructions

1. Prior Work Experience Starting From Current Job

a. I will ask you the overall or average level of stress you feel on your arm while performing your present job as well as performing previous jobs. (Remember, “arm” is from your elbow to fingertips).
b. Concentrate on your dominant arm.
c. Please rate the overall or average level of physical stress you feel on your arm for your current job including all rotations.
d. What job were you performing before this job?
e. Please rate the overall or average level of physical stress on you arm for your previous job(s).
f. Follow steps d and e for other previous jobs up to a total of **5 previous jobs or 10 years of employment**.

2. Standardized Grip Force (10Kg), Dominant Hand

a. Please grip this device and **slowly** increase your force until the pointer is in the red area. (*Don and Richard will modify grip dynamometers so that there is a pointer and red area in the back of the gauge corresponding to 10 Kg.*) Keep holding it until I ask you to relax.
b. Concentrate on your dominant arm. (Remember, arm is hand/wrist/forearm/elbow). I will ask you to rate the level of physical stress you feel in your dominant arm.
c. Let the worker apply force for 3-4 seconds.
d. Please rate the level of physical stress on your arm.

3. Beginning and End of Shift Ratings

a. Some people feel the same stress on their hand/wrist/forearm/elbow throughout the shift. Others feel different levels of physical stress at the beginning and end of a shift (job rotation included).
b. Concentrate on your dominant arm.
c. Please rate the overall or average level of physical stress on your arm at the beginning of your work shift on a typical workday. (Remember, “arm” is from your elbow to your fingertips.)
d. Please rate the overall or average level of physical stress on your arm at the end of your work shift on a typical workday. (Remember, “arm” is from your elbow to your fingertips.)

4. Matching Grip Force

1. When you use this (name of the tool or work piece), you apply a certain amount of pressure to hold it while using it.
2. Please hold this device (dynamometer) and apply the same amount of pressure that you apply when holding the hand tool/work piece.

5. Matching Pinch Force
Select the Type of Pinch Used by the Worker and Note it Down
(Lateral, 2 point, 3 point, Use 3 point for Palmer)

1. When you use this (name of the tool or work piece) or perform this task, you apply a certain amount of pressure to hold the (tool or work piece) while using it.
2. Please hold this device (pinch meter) and apply the same amount of pressure that you apply when holding the (tool or work piece).

6. Matching Thrust Force

1. When you use this (name of tool), you apply a certain amount of pressure to push the tool while using it. (Often it will be pushing down but it could be horizontal).
2. Please hold this device and push it with the same amount of pressure that you use when pushing your hand tool.

7. Instructions For Borg Scale-Estimating Force for the Job

1. Think about performing your job just **ONE** time or for **ONE** exertion. **DO NOT** think about getting tired from doing your job for your entire shift.
2. If you were to produce one (part/unit/perform one cycle) then rate the average or overall level of physical stress you feel on your RIGHT arm.
3. If you were to produce one (part/unit/perform one cycle) then rate the maximum level of physical stress you feel on your RIGHT arm.
4. If you were to produce one (part/unit/perform one cycle) then rate the average or overall level of physical stress you feel on your LEFT arm.
5. If you were to produce one (part/unit/perform one cycle) then rate the maximum level of physical stress you feel on your LEFT arm.

General Instructions

1. Using this rating scale *(place the Borg CR-10 Scale in front of the worker)*, I will ask you to rate the level of physical stress you feel while performing your job.
2. Choose the words that best describe the level of physical stressyou feel.
3. Do this for both your right arm and your left arm separately.
4. For all my questions please concentrate on your hand/wrist/forearm/elbow. This is the area between your elbowand your fingertips. We will refer to this area as “arm”.
5. Concentrating only on this area, rate the level of physical stress and where you feel it the most (for example: I feel the most stress in the wrist).
6. DO NOT think about stresses to other parts of the body (such as upper arm, shoulders, neck or back).
7. You do several things to produce one (*product name*) and some of these things may be harder on your arm than others.
   I will ask you to rate:
   a. On the average or overall, how hard this job is on your arm.
   b. Give me a rating for the activity you find to be the hardest on your arm.

Position / Worker Specific Data Form Instructions

1. **Prior Work Experience Starting From Current Job**
    - **a.** I will ask you the overall or average level of stress you feel on your arm while performing your present job as well as performing previous jobs. (Remember, "arm" is from your elbow to fingertips).
    - **b.** Concentrate on your right/left (dominant) arm.
    - **c.** Please rate the overall or average level of physical stress you feel on your right/left arm for your current job including all job stations you rotate to.
    - **d.** What job were you performing before this job?
    - **e.** Please rate the overall or average level of physical stress on your right/left arm for your previous job(s).
    - **f.** Follow steps d and e for other previous jobs up to a total of a maximum of **5 previous jobs or 10 years of employment**.
2. **Standardized Grip Force (10Kg), Dominant Hand**
    - **a.** Please grip this device and **slowly** increase your force until the pointer covers the white area (Shoulder 0º, Elbow 90º). Keep holding it until I ask you to relax.
    - **b.** Concentrate on your right/left (dominant) arm. (Remember, arm is hand/wrist/forearm/elbow). I will ask you to rate the level of physical stress you feel in your dominant arm.
    - **c.** Let the worker apply force for 3-4 seconds.
    - **d.** Please rate the level of physical stress on your arm.
3. **Beginning and End of Shift Ratings**
    - **a.** Some people feel the same stress on their hand/wrist/forearm/elbow throughout the shift. Others feel different levels of physical stress at the beginning and end of a shift (job rotation included).
    - **b.** Concentrate on your dominant arm.
    - **c.** Please rate the overall or average level of physical stress on your arm at the beginning of your work shift on a typical workday. (Remember, "arm" is from your elbow to your fingertips.)
    - **d.** Please rate the overall or average level of physical stress on your arm at the end of your work shift on a typical workday. (Remember, "arm" is from your elbow to your fingertips.)

What is an Exertion
Force Level Ratings

1. Movements at the elbow or shoulder <u>do not</u> count as an exertion.

2. Exertion is gripping, pinching, holding weights applying force for example pushing,/pulling something with the hand (button pushing)

3. Exertion should affect the muscles on the forearm or the intrinsic muscles in your hand.

4. In a continuous cyclic manner, wrist flexion and then extension counts as <u>ONE</u> exertion.

5. Forearm rotation for example pronation and supination is <u>ONE</u> exertion. This is treated different than forearm rotation.

6. Picking up something with palm down using a palmer grasp in a continuous motion, quickly turn palm up (grasp does not change is <u>ONE</u> exertion not 2 exertions. However, if you grasp something with palm down and hold it for 1 second or more and turn your palm up, then there are <u>two</u> exertions (note the 2 different force levels).

7. Inspection Task- You twist your wrist (flexion, extension, ulnar deviation, radial deviation) this is <u>ONE</u> exertion. Again you twist your wrist = <u>2nd</u> exertion. If the pause in motion is more than 1 second and flexion to extension is greater than 45° this is a separate exertion.

8. Pushing and pulling motion normally occurs at the elbow or shoulder. You are only grasping the object or maintaining contact with the object. All this motion is <u>ONE</u> exertion which is grasping.

9. Lifting between floor and waist height is low stress on the wrist. Therefore, the Borg rating should reflect this point.

10. **Regrasp**- Start with pinching something, for example taking something out of a tray, then if you quickly flip/toss the object up into the hand and change it to a power grasp, this would be considered <u>TWO</u> exertions.
    1. Pinching
    2. Other power grasp

11. For the purpose of exertion there are 2 types of grips, one is pinch (2 point, 3 point 4 point, palmer, lateral pinch, scissor pinch) and the other is grasp (power, hook, palmer, oblique). Do not differentiate between the different types of pinch or different types of grasp.

    a. When holding a part/tool, in one hand (i.e. open hand straightening of wires) that item is less than 1lb. Borg rating will = 0 and exertion and duration will not be counted. If item is greater than 1 lb. the Borg rating is 0.5.
    b. If a part/tool is being held with a controlled grasp and regardless of whether the tool is being used, exertion is one with a Borg rating of 1.

Force Level Ratings

1. Use field 9 on Job Specific Data Form if available to help identify major sub tasks.

2. Peak force sub task should not be lower then the lowest value of field 15h or 15i. In general the peak subtask should equal the force rating of field 15h.

3. When you fill out the form you need to fill out the task description in detail!

Appendix B:

Health Outcomes Data Collection Instruments

APPENDIX B.1

Questionnaire

Upper Limb Musculoskeletal Disorders: Baseline Questionnaire

Directions:

Please answer each question by pointing the arrow with the mouse and clicking with you index finger to either mark "yes" or "no" or to fill in a blank. If you need help or have any questions please ask one of our research assistants. We're happy to help!

Code # ________________________
Date: _________________________

Upper Limb Musculoskeletal disorders: Baseline Questionnaire

1. Your Company's name: ______________________________________

2. Job Title / Department: _________________________________

3. Age: ____._ (in tenths of a year)

4. Gender: ____Male ____Female

5. Are you:
   ____ Right-handed
   ____ Left-handed
   ____ Use both hands equally

6. Are you planning on leaving or retiring (from this company) in the next 3 years? ______ Yes ______ No *If yes, please ask the research assistant before going on.*

7. How long have you worked in your current job? _______years ________months

8. Do you get any of the following types of exercise (outside of work) on a regular basis?

Type of Exercise	Yes	No	Number of months per year	Average number of times per week	Average number of minutes each time
Aerobics, Jazzercise			Months	Per week	Minutes
Running, Jogging			Months	Per week	Minutes
Walking			Months	Per week	Minutes
Bicycling			Months	Per week	Minutes
Swimming			Months	Per week	Minutes
Weight Lifting			Months	Per week	Minutes
Baseball			Months	Per week	Minutes
Basketball			Months	Per week	Minutes
Football			Months	Per week	Minutes
Racquetball			Months	Per week	Minutes
Handball			Months	Per week	Minutes
Tennis			Months	Per week	Minutes
Snow Skiing or Snowboarding			Months	Per week	Minutes
Water Skiing or Wave Runner			Months	Per week	Minutes
Other (please list)			Months	Per week	Minutes

9. Do you have hobbies that involve repetitive use of your hands (outside of work) such as any of the following?

Type of Hobby	Yes	No	Number of months per year	Average number of times per week	Average number of minutes each time
Computer, Internet			Months	Per week	Minutes
Knitting, Sewing, Needlepoint, Crocheting, Arts and Crafts			Months	Per week	Minutes
Gardening, Landscaping			Months	Per week	Minutes
Snow Shoveling			Months	Per week	Minutes
Maintenance (e.g. car or engine repair), Mechanical Work			Months	Per week	Minutes
Practicing or Playing the Piano			Months	Per week	Minutes
Other Musical Instruments (please specify)			Months	Per week	Minutes
Driving a motorcycle or ATV			Months	Per week	Minutes
Snowmobiling.			Months	Per week	Minutes
Woodworking, furniture building or repair			Months	Per week	Minutes
Remodeling or building a home			Months	Per week	Minutes
Using a chainsaw (e.g. cutting wood) or other vibrating tools			Months	Per week	Minutes
Other (please specify)			Months	Per week	Minutes
Other (please specify)			Months	Per week	Minutes

10. Are you currently:
   a. Pregnant? ____ Yes ____ No
      i. If yes, when is your due date ________/_______/_______
         Month Day Year
   b. Have your periods become irregular or stopped or have you experienced things such as hot flashes? ____ Yes ____ No
      i. If yes, for how many years? ______ Years
      ii. If yes, how long has it been since your last period? ______ _______
         Month Year
   c. Have you used Estrogen replacement (or Hormone Replacement Therapy) ____ Yes ____ No
      i. If yes, how many years have you used Estrogen replacement or Hormone Replacement Therapy? ________ Years
      ii. Did you quit taking Estrogen replacement or Hormone Replacement in the past year? ____ Yes ____ No

11. Have you ever been told by a physician that you have any of the following:

   a. Diabetes: ___ Yes ___ No
      Approximately how many years ago was this diagnosed? __________Years
      With which of the following are you treating the Diabetes?
      ____ Insulin
      ____ Pills / Oral Agents ____
      Both Insulin and Pills ____ Diet
      only (no insulin or pills)
   b. Have you ever been diagnosed with Rheumatoid arthritis, Lupus, or another inflammatory arthritis (not typical Osteoarthritis or Degenerative Arthritis).
      ___ Yes ___ No
      Approximately how many years ago was this diagnosed? __________Years

c. Osteoarthritis or Degenerative Arthritis ___ Yes ___ No

i. If yes, what joints have been affected? (check all that apply)

☑	Body Part	Which side is affected? Right	Left	Both	How many years ago was this diagnosed?
☐	Fingers	☐	☐	☐	Years
☐	Wrists	☐	☐	☐	Years
☐	Elbows	☐	☐	☐	Years
☐	Shoulders	☐	☐	☐	Years
☐	Neck	☐	☐	☐	Years
☐	Back	☐	☐	☐	Years
☐	Knees	☐	☐	☐	Years
☐	Hips	☐	☐	☐	Years
☐	Ankles	☐	☐	☐	Years
☐	Toes	☐	☐	☐	Years

d. Thyroid problem: ___ Yes ___ No
Approximately how many years ago was this diagnosed? __________Years

e. Gout: ___ Yes ___ No
Approximately how many years ago was this diagnosed? __________Years

f. Kidney Failure: ___ Yes ___ No
Approximately how many years ago was this diagnosed? __________Years

g. High Blood Pressure: ___ Yes ___ No
Approximately how many years ago was this diagnosed? __________Years

h. High cholesterol (Laboratory test result over 200 mg/dL) ___ Yes ___ No
Approximately how many years ago was this diagnosed? __________Years

i. Other:____________________________(please specify) ___ Yes ___ No
Approximately how many years ago was this diagnosed? __________Years

j. Other:___________________________(please specify) ___ Yes ___ No
Approximately how many years ago was this diagnosed? _________Years

k. Other:___________________________(please specify) ___ Yes ___ No
Approximately how many years ago was this diagnosed? _________Years

l. Other:___________________________(please specify) ___ Yes ___ No
Approximately how many years ago was this diagnosed? _________Years

m. Other:___________________________(please specify) ___ Yes ___ No
Approximately how many years ago was this diagnosed? _________Years

n. Other:___________________________(please specify) ___ Yes ___ No
Approximately how many years ago was this diagnosed? _________Years

o. Other:___________________________(please specify) ___ Yes ___ No
Approximately how many years ago was this diagnosed? _________Years

p. Other:___________________________(please specify) ___ Yes ___ No
Approximately how many years ago was this diagnosed? _________Years

q. Other:___________________________(please specify) ___ Yes ___ No
Approximately how many years ago was this diagnosed? _________Years

r. Other:___________________________(please specify) ___ Yes ___ No
Approximately how many years ago was this diagnosed? _________Years

12. Has any one in your family (blood relatives only) ever been diagnosed with Carpal Tunnel Syndrome? _____ Yes _____ No

13. What is your height? ______ feet ______ inches

14. What is your current weight? ______ lbs.

15. What is the most you weighed in your life? _______ lbs.

16. What was your weight when you were 20 years old? ________ lbs.

17. Marital Status:
____ Never married (Single)
____ Currently married
____ Divorced
____ Separated
____ Widowed

18. What is the highest grade in school that you completed?
____ 8th grade or less
____ Some high school
____ High school graduate or GED
____ Some college
____ College graduate (Bachelor's Degree or higher)

19. How often do you have family problems that irritate or bother you?
____ Never
____ Occasionally
____ Often
____ Always

20. Have you ever smoked tobacco?
___ Never
___ Yes, current
___ Yes, but smoked in the past
If never, go to question 22…otherwise
How old were you when you started smoking? _____ *years old*
How old were you when you quit smoking, if you quit?_____ *years old*
On average, how many cigarettes did/do you smoke per day?______

21. How many cups of caffeinated coffee do you drink in an average day?
_____ Number of cups per day

22. How many 12 oz. glasses (one can) of caffeinated beverages (e.g. Coke, Pepsi) do you drink in an average day?
_____ Number of glasses per day

23. Over the past year, how much alcohol do you drink in an average week?
(1 drink = 12 oz. beer, 6 oz. wine, or 1 oz. liquor)
_____ None
_____ 1-2 drinks per week
_____ 3-5 drinks per week
_____ 6-11 drinks per week
_____ 12-17 drinks per week
_____ 18-23 drinks per week
_____ 24-29 drinks per week
_____ 30 or more drinks per week

24. In the past, have you ever had a problem with alcohol? ____ Yes ____ No
    a. If yes, approximately how many years ago? _________ Years

25. How would you describe your general health compared to others of your own age?
    ____ Much Better
    ____ Somewhat Better
    ____ The Same
    ____ Somewhat Worse
    ____ Much Worse

26. How often during the past year have you felt "down", blue or depressed?
    ____ Never
    ____ Seldom
    ____ Often
    ____ Always

27. How often are you physically exhausted after work?
    ____ Never
    ____ Seldom
    ____ Often
    ____ Always

28. How often are you mentally exhausted after work?
    ____Never
    ____ Seldom
    ____ Often
    ____ Always

29. Do you get along with your co-workers?
    ____ Always
    ____ Often
    ____ Occasionally
    ____ Never

30. All in all, how satisfied are you with your job?
    ____ Very satisfied
    ____ Satisfied
    ____ Neither satisfied nor dissatisfied
    ____ Dissatisfied
    ____ Very dissatisfied

31. Does your supervisor demonstrate his or her appreciation for the work that you do?
____ Always
____ Often
____ Occasionally
____ Never

32. How strongly would you recommend your job to someone else?
____ Strongly recommend
____ Recommend
____ Neither recommend nor discourage
____ Discourage
____ Strongly discourage

33. If you were looking for a new job now, how likely is it that you would decide to take this job again?
____ Very likely
____ Likely
____ Neither likely nor unlikely
____ Unlikely
____ Very unlikely

34. My employer cares about my health and safety on the job.
____ Strongly agree
____ Agree
____ Neither agree nor disagree
____ Disagree
____ Strongly Disagree

Thank you for completing the questionnaire.

APPENDIX B.2

Structured Interview

Plant: ______________________

Code # ______________________

Date: ______________________

Baseline Structured Interview (to be completed on a laptop computer)

At the current time or at any time in the past <u>month</u> have you had any pain, ache, stiffness, numbness or tingling in any of the following body parts? (check all that apply and refer to the body diagram so the worker can note <u>all</u> areas that apply

Body part	Yes	No	Symptoms in this body part	Pain / Ache / Burning / Stiffness	Pain Severity Rating (1-10)	Current Pain / Ache / Burning / Stiffness Symptoms	Total Pain Duration (days)	Tingling / Numbness	Current Numbness / Tingling Symptoms	Total Numbness / Tingling Duration (days)
1. Neck **(A)**										
				□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
2. Shoulder										
Interscapular **(D)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
R. Nape of the Neck **(C)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
R. Periscapular **(G)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
R. Shoulder (Glenohumeral) **(H)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
R. Upper Arm **(J)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
L. Nape of the Neck **(B)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
L. Periscapular **(F)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
L. Shoulder (Glenohumeral) **(E)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
L. Upper Arm **(I)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
3. Elbow										
R. Medial Elbow **(N)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
R. Lateral Elbow **(P)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
R. Elbow (Other) **(O)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
R. Forearm **(R)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days

L. Medial Elbow **(M)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
L. Lateral Elbow **(K)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
L. Elbow (Other) **(L)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
L. Forearm **(Q)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
4. Wrist										
R. Wrist **(T)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
L. Wrist **(S)**			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
5. Hand										
R. thumb			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
R. index finger			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
R. middle/long finger			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
R. ring finger			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
R. 5th/pinky finger			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
L. thumb			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
L. index finger			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
L. middle/long finger			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
L. ring finger			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days
L. 5th/pinky finger			□Yes □No	□Yes □No		□Yes □No	Days	□Yes □No	□Yes □No	Days

1. (Computer selects the body part noted to have been affected in the prior question) In the past month, have you missed work or changed jobs because of problems with the _________body part?

☐ No Missed work, Lost time, or moved to another job.

Body part	Lost time / Missed work	Moved to another job	Number of Days missed work
1. Neck **(A)**	☐Yes ☐No	☐Yes ☐No	Days
2. Shoulder			
Interscapular **(D)**	☐Yes ☐No	☐Yes ☐No	Days
R. Nape of the Neck **(C)**	☐Yes ☐No	☐Yes ☐No	Days
R. Periscapular **(G)**	☐Yes ☐No	☐Yes ☐No	Days
R. Shoulder (Glenohumeral) **(H)**	☐Yes ☐No	☐Yes ☐No	Days
R. Upper Arm **(J)**	☐Yes ☐No	☐Yes ☐No	Days
L. Nape of the Neck **(B)**	☐Yes ☐No	☐Yes ☐No	Days
L. Periscapular **(F)**	☐Yes ☐No	☐Yes ☐No	Days
L. Shoulder (Glenohumeral) **(E)**	☐Yes ☐No	☐Yes ☐No	Days
L. Upper Arm **(I)**	☐Yes ☐No	☐Yes ☐No	Days
3. Elbow			
R. Medial Elbow **(N)**	☐Yes ☐No	☐Yes ☐No	Days
R. Lateral Elbow **(P)**	☐Yes ☐No	☐Yes ☐No	Days
R. Elbow (Other) **(O)**	☐Yes ☐No	☐Yes ☐No	Days
R. Forearm **(R)**	☐Yes ☐No	☐Yes ☐No	Days
L. Medial Elbow **(M)**	☐Yes ☐No	☐Yes ☐No	Days
L. Lateral Elbow **(K)**	☐Yes ☐No	☐Yes ☐No	Days
L. Elbow (Other) **(L)**	☐Yes ☐No	☐Yes ☐No	Days

L. Forearm **(Q)**	☐Yes ☐No	☐Yes ☐No	Days
4. Wrist			
R. Wrist **(T)**	☐Yes ☐No	☐Yes ☐No	Days
L. Wrist **(S)**	☐Yes ☐No	☐Yes ☐No	Days
5. Hand			
R. thumb	☐Yes ☐No	☐Yes ☐No	Days
R. index finger	☐Yes ☐No	☐Yes ☐No	Days
R. middle/long finger	☐Yes ☐No	☐Yes ☐No	Days
R. ring finger	☐Yes ☐No	☐Yes ☐No	Days
R. 5th/pinky finger	☐Yes ☐No	☐Yes ☐No	Days
L. thumb	☐Yes ☐No	☐Yes ☐No	Days
L. index finger	☐Yes ☐No	☐Yes ☐No	Days
L. middle/long finger	☐Yes ☐No	☐Yes ☐No	Days
L. ring finger	☐Yes ☐No	☐Yes ☐No	Days
L. 5th/pinky finger	☐Yes ☐No	☐Yes ☐No	Days

2. (For those indicating a history of numbness OR tingling in the hand/wrist/fingers in question #1):
   How long all together have you had tingling and/or numbness? ___________ months
   Is or was the numbness or tingling in your hands (check all that apply)…
   _____ worse at night
   _____ present on awakening in the morning that resolves within ½ hour
   _____ worse with holding an object (e.g., steering wheel, tool or newspaper)
   _____ Intermittent
   _____ Continuous   If continuous how many months has it been continuous? ________ months

3. Do you ever have numbness and/or tingling in your…
   Right foot/leg? ___ Yes ___ No
   Left foot/leg? ___ Yes ___ No

4. Have you ever had snapping or locking of a finger? _____ Yes _____ No
If yes, Which finger(s)? Right _________________________________ Left ___________________________________

5. Have you ever been told by a medical doctor that you have/had any of the following disorders?

Disorder	Yes	No	Right, Left, Bilateral	Year of Diagnosis
Thoracic Outlet Syndrome				
Rotator Cuff Tear				
Rotator Cuff Tendonitis or Shoulder Tendinitis				
Lateral Epicondylitis (Tennis Elbow)				
Medial Epicondylitis (Golfer's Elbow)				
Cubital Tunnel Syndrome (Ulnar nerve problem at the elbow)				
DeQuervains				
Hand / Wrist / Forearm Fracture				
Hand/Wrist Tendonitis				
Carpal Tunnel Syndrome				
Raynaud's Disease				
Trigger Finger				

6. Have you ever had a pinched nerve (e.g. sciatica)? _____ Yes _____ No

If yes, was the pinched nerve in the back? _____ Yes _____ No
Was the pinched nerve in the neck? _____ Yes _____ No

7. Have you ever had a broken bone or fracture? _____ Yes _____ No
If yes, which did you fracture?
R. Clavicle _____ Yes _____ No
L. Clavicle _____ Yes _____ No
R. Humerus _____ Yes _____ No
L. Humerus _____ Yes _____ No

R. Radius _____ Yes _____ No
L. Radius _____ Yes _____ No
R. Ulna _____ Yes _____ No
L. Ulna _____ Yes _____ No
R. Wrist _____ Yes _____ No
L. Wrist _____ Yes _____ No
R. digit(s) _____ Yes _____ No
L. digit(s) _____ Yes _____ No

8. Have you ever dislocated a joint? _____ Yes _____ No

If yes, which joint(s) have you dislocated?
R. Shoulder _____ Yes _____ No
L. Shoulder _____ Yes _____ No
R. Elbow _____ Yes _____ No
L. Elbow _____ Yes _____ No
R. Wrist _____ Yes _____ No
L. Wrist _____ Yes _____ No
Other ___________________________
____
____

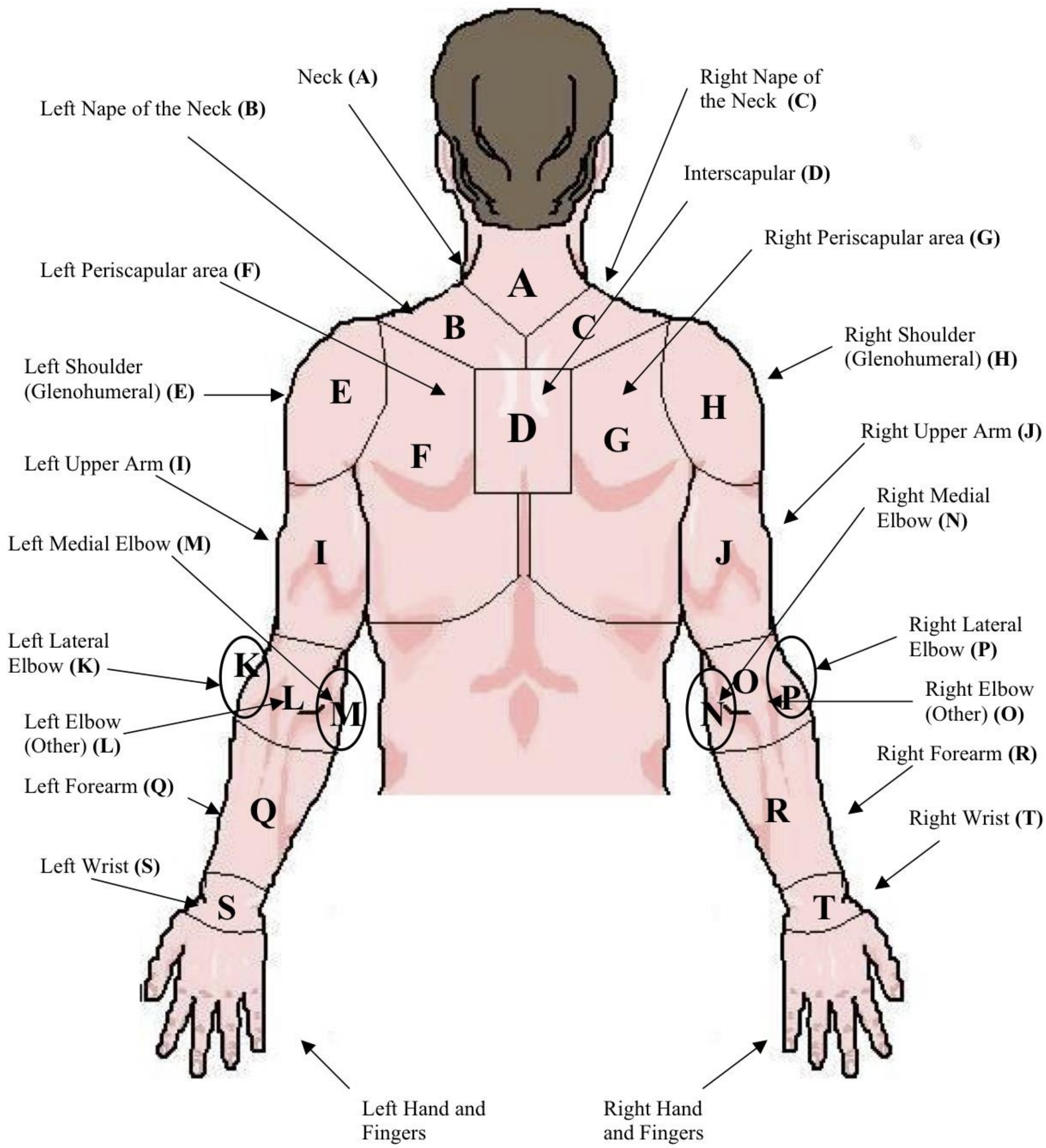
9. Have you ever had surgery other than dental, tonsillectomy, C-section or hernia repair? _____ Yes _____ No
If yes, what surgeries?
____
____

10. Have you been hospitalized other than for surgery or childbirth? _____ Yes _____ No
If yes, for what problem(s) or diagnoses?
____
____

APPENDIX B.3

Sectioned Upper Extremity and Upper Torso Body Diagram

Body Diagram for Structured Interviews



APPENDIX B.4

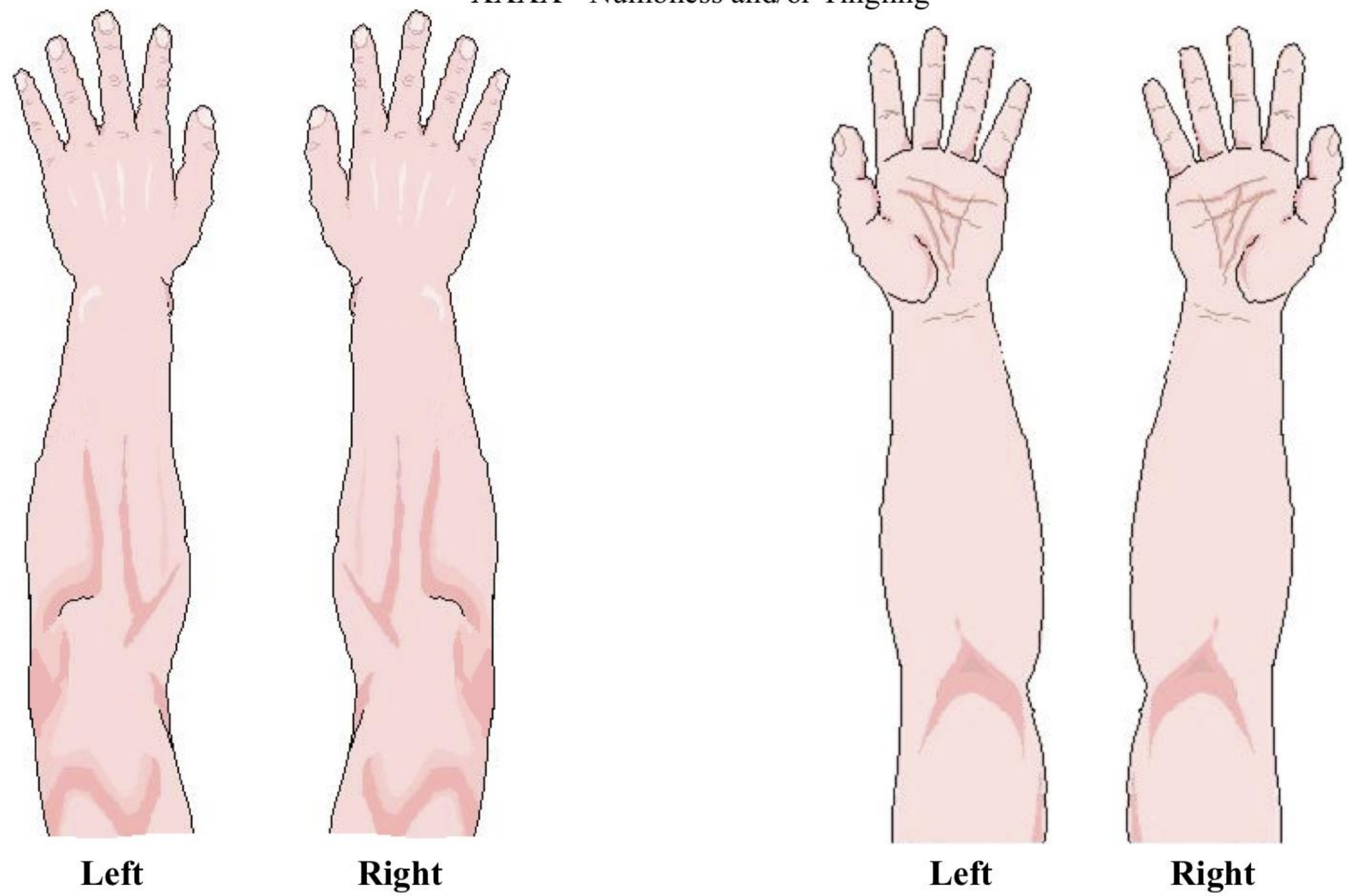
Hand and Digit Pain Diagram

Hand Symptoms Diagram

Plant:__________________________
Code #__________________________
Date:__________________________
Examiner:__________________________

Please mark each area on your hand and arm where you are experiencing any pain, ache, burning, numbness and/or tingling. If you have any questions please ask. Please mark all hand diagrams with pertinent information.

OOOO - Pain, Ache, Burning and/or Stiffness
XXXX - Numbness and/or Tingling



APPENDIX B.5

Physical Examination Form

Plant: ___________________________
Code # __________________________
Date: ___________________________

Physical Examination Form (all physicals)

1. Heart Rate __________beats/min
2. Blood Pressure _________mmHg / ________mmHg
   Systolic Diastolic

	Right	**Left**
3. Wrist Depth	____ mm	_____ mm
4. Wrist Width	____ mm	_____ mm
5. Measured Weight	_________kg	
6. Measured Height	__________cm	

Body region	Sign	1st Examiner		2nd Examiner	
		+ Abnormal	- Normal	+ Abnormal	- Normal
Neck	Abnormal Cervical ROM (Flexion less than 2 cm from the sternum)				
	R. Spurlings (Right Neck Rotation)				
	R. Middle Upper Trapezius **"Pain"**				
	R. Levator Scapulae **"Pain"**				
	R. Rhomboid Major **"Pain"**				
	L. Spurlings (Left Neck Rotation)				
	L. Middle Upper Trapezius **"Pain"**				
	L. Levator Scapulae **"Pain"**				
	L. Rhomboid Major **"Pain"**				
R. Shoulder	Painful Arc				
	Shoulder Abduction ROM less than 160 degrees				
	Impingement Sign (Neer)				
	Supraspinatus Test (Empty Can test)				
	External Rotator Weakness				
	Bicipital Tendon Test (Resisted Elbow Flexion)				
L. Shoulder	Painful Arc				
	Shoulder Abduction ROM less than 160 degrees				
	Impingement Sign (Neer)				
	Supraspinatus Test (Empty Can test)				
	External Rotator Weakness				
	Bicipital Tendon Test (Resisted Elbow Flexion)				

Plant: ___________________ Code # _________________________ Date: __________________________

Region	Sign	1st Examiner + Abnormal	1st Examiner - Normal	2nd Examiner + Abnormal	2nd Examiner - Normal
R. Elbow	Tender Point 1 (Retro Lateral Epicondyle)				
	Tender Point 2 (Lateral Epicondyle)				
	Tender Point 3 (Between Lateral Epicondyle and Radial Head)				
	Tender Point 4 (Radial Head)				
	Tender Point 5 (1 cm Distal to the Radial Head)				
	Tender Point 6 (Radial Tunnel)				
	Tender Medial Epicondyle				
	Tender 1 cm Distal to the Medial Epicondyle				
	Resisted Wrist / Phalangeal Extension (Lateral Epicondylitis pain/soreness/etc.)				
	Lateral epicondyle pain with resisted middle finger extension				
	Resisted Wrist / Phalangeal Flexion (Medial Epicondylitis pain/soreness/etc.)				
	Tinel's Retrocondylar Groove (to Distal Forearm)				
	Tinel's Cubital Tunnel (to Distal Forearm)				
L. Elbow	Tender Point 1 (Retro Lateral Epicondyle)				
	Tender Point 2 (Lateral Epicondyle)				
	Tender Point 3 (Between Lateral Epicondyle and Radial Head)				
	Tender Point 4 (Radial Head)				
	Tender Point 5 (1 cm Distal to the Radial Head)				
	Tender Point 6 (Radial Tunnel)				
	Tender Medial Epicondyle				
	Tender 1 cm Distal to the Medial Epicondyle				
	Resisted Wrist / Phalangeal Extension (Lateral Epicondylitis pain/soreness/etc.)				
	Lateral epicondyle pain with resisted middle finger extension				
	Resisted Wrist / Phalangeal Flexion (Medial Epicondylitis pain/soreness/etc.)				
	Tinel's Retrocondylar Groove (to Distal Forearm)				
	Tinel's Cubital Tunnel (to Distal Forearm)				

Mark All Positive Findings

Mark All Positive Findings

Plant: __________________ Code # ________________________ Date: _________________________

Region	Sign	1st Examiner + Abnormal	1st Examiner - Normal	2nd Examiner + Abnormal	2nd Examiner - Normal
R. Wrist	FCR – tenderness				
	FCU – tenderness				
	Flexor tendon- tenderness				
	1st compartment tenderness				
	Tender over Extensor Compartment (not 1st compartment)				
	If yes, which Compartment?				
	ECU tenderness				
	Resisted wrist flexion with pain at FCR				
	Resisted wrist flexion with pain at FCU				
	Resisted Phalangeal Flexion				
	Finkelstein's (1st Ext. Comp. pain/soreness/etc.)				
	Pain in Extensor Tendon with resisted Phalangeal extension (not 1st compartment)				
	Pain in ECU with resisted extension				
	Phalen's 60 second test (≥ 2 median nerve digits)				
	Tinel's Proximal Carpal Tunnel (≥ 2 median nerve digits)				
	Tinel's Mid-Carpal Tunnel (≥ 2 median nerve digits)				
	Tinel's Distal Carpal Tunnel (≥ 2 median nerve digits)				
L. Wrist	FCR – tenderness				
	FCU – tenderness				
	Flexor tendon- tenderness				
	1st compartment tenderness				
	Tender over Extensor Compartment (not 1st compartment)				
	If yes, which Compartment?				
	ECU tenderness				
	Resisted wrist flexion with pain at FCR				
	Resisted wrist flexion with pain at FCU				
	Resisted Phalangeal Flexion				
	Finkelstein's (1st Ext. Comp. pain/soreness/etc.)				
	Pain in Extensor Tendon with resisted Phalangeal extension (not 1st compartment)				
	Pain in ECU with resisted extension				
	Phalen's 60 second test (≥ 2 median nerve digits)				
	Tinel's Proximal Carpal Tunnel (≥ 2 median nerve digits)				
	Tinel's Mid-Carpal Tunnel (≥ 2 median nerve digits)				
	Tinel's Distal Carpal Tunnel (≥ 2 median nerve digits)				

Plant: ____________________ Code # _________________________ Date: __________________________

Region	Sign	1st Examiner		2nd Examiner	
		+ Abnormal	- Normal	+ Abnormal	- Normal
R. Fingers	Thumb – A1 tenderness				
	Tendon Nodule				
	Locking / Triggering				
	Index – A1 tenderness				
	Tendon Nodule				
	Locking / Triggering				
	Middle finger – A1 tenderness				
	Tendon Nodule				
	Locking / Triggering				
	Ring finger – A1 tenderness				
	Tendon Nodule				
	Locking / Triggering				
	5^{th} digit – A1 tenderness				
	Tendon Nodule				
	Locking / Triggering				
	CMC Deformity				
	CMC Grind Test				
L. Fingers	Thumb – A1 tenderness				
	Tendon Nodule				
	Locking / Triggering				
	Index – A1 tenderness				
	Tendon Nodule				
	Locking / Triggering				
	Middle finger – A1 tenderness				
	Tendon Nodule				
	Locking / Triggering				
	Ring finger – A1 tenderness				
	Tendon Nodule				
	Locking / Triggering				
	5^{th} digit – A1 tenderness				
	Tendon Nodule				
	Locking / Triggering				
	CMC Deformity				
	CMC Grind Test				

7. Signs of Rheumatoid Arthritis ____ Yes ____ No
8. Heberden's Nodes ____ Yes ____ No
   If yes, which joint(s)____
9. Bouchards Nodes ____ Yes ____ No
   If yes, which joint(s)____

	Right	Left
10. Dorsal Wrist Ganglia	___ Yes ___ No	___Yes ___ No
11. Volar Wrist Ganglia	___ Yes ___ No	___Yes ___ No
12. Dupuytren's contracture	___ Yes ___ No	___Yes ___ No

Other findings in the physical exam:

Body Part	Test performed	Positive finding	Negative finding	Examiner	
				1st	2nd

Current Musculoskeletal Disorder(s)

Right	Left	Diagnostic Impression

Prior/Past Musculoskeletal Disorder(s)

Right	Left	Diagnostic Impression

APPENDIX B.6

Nerve Conduction Form

Plant:__________________________
Subject ID #______________________
Date:___________________________
Examiner:________________________

Nerve Conduction Data Form

Right Hand

Transcarpal	**Digital Sensory**	**Motor**
Distance ___ 8 cm ___ ( )	Distance _____14 cm ___( )	Distance ____ 8 cm ____ ( )
Median Latency (msec)	Median Latency (msec)	Median Latency (msec)
Median Amplitude (μVs)	Median Amplitude (μVs)	Median Amplitude (K)
Ulnar Latency (msec)	Ulnar Latency (msec)	Ulnar Latency (msec)
Ulnar Amplitude (μVs)	Ulnar Amplitude (μVs)	Ulnar Amplitude (K)
Comments	Comments:	Comments

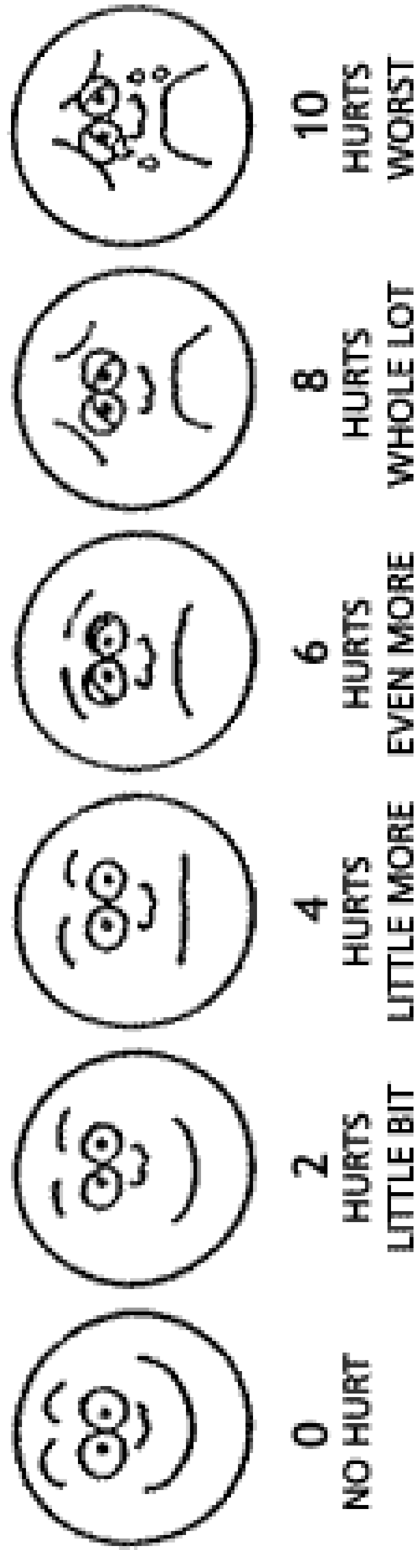
Left Hand

Transcarpal	**Digital Sensory**	**Motor**
Distance ___ 8 cm ___ ( )	Distance ____14 cm ____( )	Distance ____ 8 cm ____ ( )
Median Latency (msec)	Median Latency (msec)	Median Latency (msec)
Median Amplitude (μVs)	Median Amplitude (μVs)	Median Amplitude (K)
Ulnar Latency (msec)	Ulnar Latency (msec)	Ulnar Latency (msec)
Ulnar Amplitude (μVs)	Ulnar Amplitude (μVs)	Ulnar Amplitude (K)
Comments	Comments	Comments

Hand Dorsum Temperature = 32° C
Median Digital Sensory → Long Finger   Ulnar Digital Sensory → Little Finger
If transcarpal delta ≥ 0.4 msec, do ulnat digital sensory and ulnar motor
If median motor latency or amplitude abnormal, map E1. If still abnormal, do median/ulnar with forearm conductions
If mapping needed for motor studies, note both original and mapped numbers in comments.

APPENDIX B.7

Pain Scale


0
NO HURT
2
HURTS
LITTLE BIT
4
HURTS
LITTLE MORE
6
HURTS
EVEN MORE
8
HURTS
WHOLE LOT
10
HURTS
WORST

Appendix C:

Job Physical Exposure Data Collection Instruments

APPENDIX C.1

Position Specific Data Form

Position / Worker Specific Data Form

1. Subject I.D. ____________________________ <AA0001>
2. Subject Name: ________________________
3. ☐Male ☐Female
4. Age: ________ <years>
5. Facility: ________________________________
6. Time (24hr): ____________________________ <2:30 pm = 14:30, midnight = 00:00>
7. Date: _________________________________ <MM / DD / YYYY>
8. Analyst #1: ___________________________
9. Analyst #2: ____________________________

Position Information

10. Line / Department Title: ____

11. Position Title: ____

12. Position Description: ____

____

____

____

13. Typical Shift ***Start*** Time (24hr): ___________

14. Typical Shift ***End*** Time (24hr): ___________

15. Break-Time (Minutes/day): ________Minutes <Total of Lunch & Breaks / Day>

16. # of ***Distinct*** Jobs Rotated to: ___________

17.

☐	☐	☐	☐	☐	☐	☐	
M	T	W	H	F	S	SU	Typical ODD WEEK <Check Days Worked, Write Total Hours/Day Below>
__	__	__	__	__	__	__	
☐	☐	☐	☐	☐	☐	☐	
M	T	W	H	F	S	SU	Typical EVEN WEEK <Check Days Worked, Write Total Hours/Day Below>
__	__	__	__	__	__	__	

18. Note Unusual Schedule Here: ____

____

19. Jobs Included in Position:

Job #	Line/Cell/ Workstation	Job Title/ Description	PACE Self, Line, Piece Rate	Cycle Time (seconds)	Production per Hour	Typical Work Hrs/Day	OR	Typical Work % of Day
1			S L P					
2			S L P					
3			S L P					
4			S L P					
5			S L P					
6			S L P					
7			S L P					
8			S L P					

1

Subject ID: ____________________________

Worker Information

20. Prior Work Experience; Back Maximum of 10 Years ***OR*** Maximum of 5 Jobs[1]:
(Include Current Position and *significantly* different prior positions with *present* employer first)

Position	Title / Description	Years	Average Borg Rating
Current			
Prior #1			
Prior #2			
Prior #3			
Prior #4			
Prior #5			

21. Do you currently work on a second job outside of this facility? Yes No

22. If Yes, 2nd Job Title/Description: ____

____

23. Average Hours/Week on 2nd Job: _________ 24. Number of Years on 2nd Job: ___________

25. Dominant Hand Overall (Average) Borg Rating for 2nd Job: ___________________________

	Trial #1	Trial #2	Trial #3	Average
26. Worker's Dominant Hand L R B (if Both, Test Right)				
27. Worker's Maximum ***Grip*** Strength (Dominant Hand, #2 Position)	kgf	kgf	kgf	kgf
28. Worker's Maximum ***Lateral Pinch*** Strength (Dominant Hand)	kgf	kgf	kgf	kgf
29. Worker's Maximum ***3-Point Pinch*** Strength (Dominant Hand)	kgf	kgf	kgf	kgf
30. Standardized Grip Force[2] (10 kgf) (Dominant Hand, Borg CR-10)	Borg CR-10			

	Worker Estimated Rating (Stress) (Dominant Hand)	Worker Rating @ Beg/End (Stress) (Dominant Hand)
31. Overall Worker Rating at ***Beginning*** of Shift[3] (Borg CR-10)		
32. Overall Worker Rating at ***End*** of Shift[3] (Borg CR-10)		

33. Analyst Notes (Optional): ____

____

____

____

APPENDIX C.2

Job Specific Data Collection Form

Job Specific Data Form

1. Subject I.D. ______________________________
<From Position Form, Field #1>
2. Analyst Name(s): ________________________
3. Cycle Time (minutes:seconds): ________________
4. Job ID (Plant Official):________________________
5. Facility: __________________________________
6. Time (24hr): _____________________________
<2:30 pm = 14:30, midnight = 00:00>
7. Date: ____________________________________
<MM / DD / YYYY>
8. Job # (From "Position Data Form, Field #19"):________

Job Overview

9. Task Borg CR-10 Estimated Ratings (To Assist with Video Analysis)*

Task	Task Description	Average Analyst Borg CR-10 Rating	
		Left (Force)	*Right* (Force)
1			
2			
3			
4			
5			

* Write down major tasks under "Task Description", assign typical Borg CR-10 ratings for hand(s) involved for each task

Video Observation (Remind worker: "I will focus on your hands & arms.")

Direct Observation (Worker Remains Working.)

	Left Hand			Right Hand		
10. Average Hand/Arm Vibration Exposure, (Circle Level(s) if Present, Indicate % of Cycle Time for ***EACH*** Level)	Neg.	Visible	Severe	Neg.	Visible	Severe
	____%	_____%	_____%	____%	_____%	_____%

	Left Hand		Right Hand	
11. Gloves (Indicate Type & Fit for ***BOTH*** Hands)	☐ *NONE* ☐ Vinyl ☐ Latex ☐ Cotton ☐ Tipless ☐ Cut-Resistant ☐ Anti-Vibration ☐ Leather ☐ Other______	☐ Tight ☐ Normal ☐ Loose	☐ *NONE* ☐ Vinyl ☐ Latex ☐ Cotton ☐ Tipless ☐ Cut Resistant ☐ Anti-Vibration ☐ Leather ☐ Other______	☐ Tight ☐ Normal ☐ Loose

12. Room Temperature: ______ºC	Left Hand	Right Hand
13. Hand Contact with Hot/Cold Objects (Indicate Temperature, % of Cycle Time and Use of Gloves for ***BOTH*** Hands)	____ºC ☐ *Not Applicable* Gloves: ☐ Yes ☐ No	____ºC ☐ *Not Applicable* Gloves: ☐ Yes ☐ No
	____% of Cycle in Contact	____% of Cycle in Contact

Job #____-1

Form #: 12082003

Subject I.D. ______________________________ Job # (From "Personal Data Form, Field #19"): __________

14. Localized Mechanical Compression (Determine Severity on Site):

	Left			Right		
	Negligible	Moderate / Severe	Exertions/cycle % of Cycle	Negligible	Moderate / Severe	Exertions/cycle % of Cycle
a. Palm		M S	Ex/Cycle:____ % of Cycle:_____		M S	Ex/Cycle:____ % of Cycle:_____
b. Wrist		M S	Ex/Cycle:____ % of Cycle:_____		M S	Ex/Cycle:____ % of Cycle:_____
c. Forearm		M S	Ex/Cycle:____ % of Cycle:_____		M S	Ex/Cycle:____ % of Cycle:_____
d. Elbow		M S	Ex/Cycle:____ % of Cycle:_____		M S	Ex/Cycle:____ % of Cycle:_____
e. Finger(s)		M S	Ex/Cycle:____ % of Cycle:_____		M S	Ex/Cycle:____ % of Cycle:_____

Worker Ratings (Final Interaction with Worker for this Job)

15. Hand / Wrist / Forearm / Elbow Force Measures:

Variables	Not Applicable	Typical Overall Exposure		Typical Peak Exposure	
		Left	*Right*	*Left*	*Right*
a. Weight of Workpiece(s) or tool(s) <kg> (supported by worker)		kg	kg	kg	kg
b. Center of Mass Offset, <inches> (Measure from Center of Grip)		in	in	in	in
c. Matching Grip Force[4], <kgf> (Dominant Hand Only)		kgf	kgf	kgf	kgf
d. Matching Pinch Force[5], <kgf> Typical Pinch Type: ☐ Lateral, ☐ 2-Point, ☐ 3-Point		kgf	kgf	kgf	kgf
e. Matching Thrust Force[6], <kgf>		kgf	kgf	kgf	kgf
f. Pushing Force, <kgf> (Analyst Measured)		kgf	kgf	kgf	kgf
g. Pulling Force, <kgf> (Analyst Measured)		kgf	kgf	kgf	kgf
h. Analyst Rating of Applied Force[7,]* (Borg CR-10, Entire Job)		CR-10	CR-10	CR-10	CR-10
i. Worker Rating of Applied Force[7,]* (Borg CR-10, Entire Job)		CR-10	CR-10	CR-10	CR-10

* Typical Stress Level Across ***ALL*** Sub-Tasks for **One** Cycle

Job #____-2

Form #: 12082003

Subject I.D. ______________________________ Job # (From "Personal Data Form, Field #19"): __________

Analysis from Video (Performed outside the plant):

16. Tool Kicks and Hand as Hammer:

	Left: Negligible	Left: Number/Cycle @ Each Severity Level – Moderate (Visible)	Left: Severe	Right: Negligible	Right: Number/Cycle @ Each Severity Level – Moderate (Visible)	Right: Severe
a. Tool Kicks						
b. Hand as Hammer						

17. HAL Rating, Hand/Wrist Posture, Forearm Rotations (All Measurements Taken from Video)				Typical Exposure %: Left Hand	Typical Exposure %: Right Hand	Typical Exposure Counts (Circle Peak Force Posture): Left Hand	Typical Exposure Counts (Circle Peak Force Posture): Right Hand
a. HAL Rating							
b. Hand/Wrist Posture (From ***Anatomical*** Neutral, Measured in degrees)							
I. Flexion (Totals 100% of Cycle)	Low <30º	Med 30º-50º	Hi >50º	L __ M __ H __	L __ M __ H __	L __ M __ H __	L __ M __ H __
II. Extension (Totals 100% of Cycle)	Low <30º	Med 30º-50º	Hi >50º	L __ M __ H __	L __ M __ H __	L __ M __ H __	L __ M __ H __
III. Ulnar Deviation (Totals 100% of Cycle)	Low <10º	Med 10º-25º	Hi >25º	L __ M __ H __	L __ M __ H __	L __ M __ H __	L __ M __ H __
IV. Radial Deviation (Totals 100% of Cycle)	Low <5º		Hi ≥5º	L __ H __	L __ H __	L __ H __	L __ H __
c. Number of Forearm Rotations per Cycle (Measure rotations ≥ ±45º, return to neutral is 1 rotation)							

18. Exertions with Elbow Included Angle <70º or >135º
(Record exertions / cycle, % of cycle, and typical forearm rotation during exertion):

	Left: Negligible	Left: <70º	Left: >135º	Right: Negligible	Right: <70º	Right: >135º
a. Number of Exertions		_____ / Cycle	_____ / Cycle		_____ / Cycle	_____ / Cycle
b. % of Cycle Time		_________ %	_________ %		_________ %	_________ %
c. Typical Forearm Position (**N**eutral, **P**rone, **S**upine)		N ☐ P ☐ S ☐	N ☐ P ☐ S ☐		N ☐ P ☐ S ☐	N ☐ P ☐ S ☐

Job #____-3

Form #: 12082003

Subject I.D. ____________________________ Job # (From "Personal Data Form, Field #19"): __________

19. Grip & Pinch Exertions for a Typical Cycle (Record % of cycle, and Grip or Pinch Span (≈ inches)):

Type of Grasp (Indicate: % of Cycle & Grip or Pinch Span)	Negligible	Left		Negligible	Right	
		% of Cycle	≈ Grip/Pinch Span*		% of Cycle	≈ Grip/Pinch Span*
a. Power/Hook Grip			inches			inches
b. Oblique Grip			inches			inches
c. Palmer Grip			inches			inches
d. Palmer Pinch			inches			inches
e. 3-Point Pinch			inches			inches
f. 2-Point Pinch			inches			inches
g. Lateral (Key) Pinch			inches			inches
h. 2-Finger "Scissor" Pinch			inches			inches

* Approximate actual span from video observation; for spans less than ~¼ inch, put 0 for Grip/Pinch Span.

Strain Index Analysis from Video:

20. Total Cycle Time = ________Seconds (As Timed at Plant, or From Video)

21. ***LEFT*** Hand Strain Index Table:

Task	Task Description	Time	Intensity of Exertion (Borg CR-10)	Number of Exertions / **Cycle**	Hand/Wrist Posture (SI Definition)	**Duration** of Exertion per **Cycle**	Speed (SI Definition)	Hours / Day
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

Subject I.D. ______________________________ Job # (From "Personal Data Form, Field #19"): __________

22. ***RIGHT*** Hand Strain Index Table:

Task	Task Description	Time	Intensity of Exertion (Borg CR-10)	Number of Exertions / **Cycle**	Hand/Wrist Posture (SI Definition)	**Duration** of Exertion per **Cycle**	Speed (SI Definition)	Hours / Day
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

23. ***Comments & Observations (Risk Factors and Concerns not Otherwise Recorded)***:

APPENDIX C.3

Borg CR-10 Scale

Borg CR-10

0.5	Very, Very Light
1	Very Light
2	Light
3	Moderate
4	Somewhat Hard
5	Hard
6	
7	Very Hard
8	
9	
10	Near Maximal

APPENDIX C.4

Grip/Pinch Diagram

Grip & Pinch Exertions
Job Specific Form

#19a:Power Grip

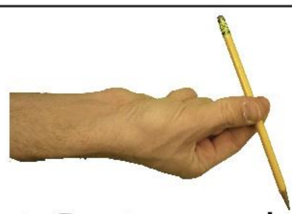
#19a:Hook Grip
Thumb is **NOT** Used

#19b:Oblique Grip

#19c:Palmer Grip

#19d:Palmer Pinch

#19e:3-Point Pinch



#19f:2-Point Pinch

#19g: Lateral Pinch

Grip & Pinch Strength Testing
Position Specific Form

#27 Power Grip

Wrist Posture: Functional Neutral
Shoulder Angle: 0°
Elbow Angle: 90°

#28: Lateral Pinch

Wrist Posture: Functional Neutral
Use: Thumb, Side of Index Finger

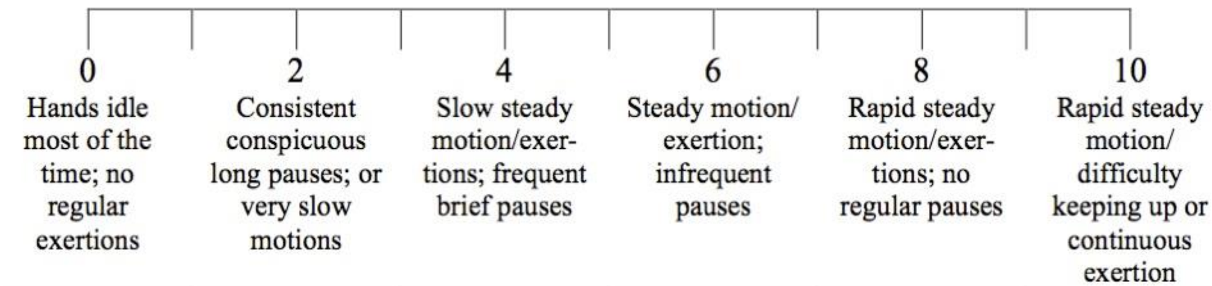
#29: 3-Point Pinch

Wrist Posture: Functional Neutral
Use: Thumb, Index & Middle Fingers

APPENDIX C.5

Hand Activity Level (HAL) Scale

HAL Scale


0
Hands idle most of the time; no regular exertions
2
Consistent conspicuous long pauses; or very slow motions
4
Slow steady motion/exer-tions; frequent brief pauses
6
Steady motion/ exertion; infrequent pauses
8
Rapid steady motion/exer-tions; no regular pauses
10
Rapid steady motion/ difficulty keeping up or continuous exertion