Exploring Associations Between Multiple Risk-Factors and Work-Related Musculoskeletal Disorders, Across Multiple Body Segments in an Automotive Manufacturing Environment

By

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Abstract

The causes of Work-Related Musculoskeletal Disorders (WMSDs) are multifactorial, with the exact pathogenesis being unknown. Current literature provides information on several studies that investigate the role of physical and individual risk factors, but very few take a holistic approach of studying multiple risk factors across multiple body segments. This proposed study addresses this research gap by exploring associations between a) Physical/Job-related, b) Individual, c) Psychophysical and d) Psychosocial risk factors and WMSDs in manufacturing environments, especially in the automotive sector that is characterized by highly repetitive tasks and component assembly. This study can facilitate true personalization of a job by investigating the combined impact of multiple risk factors simultaneously which can contribute to more accurate and specific risk assessments such as body segment risk for a specific employee working on a particular job. This study is a retrospective analysis of cross-sectional data collected by Dr. Richard Sesek along with a team of medical and engineering researchers for the UAW-Ford National Joint Committee on Health and Safety. The purpose of the original study was to analyze existing ergonomic assessment tools and propose an improved ergonomic tool to assess risks associated with automotive manufacturing and assembly tasks for the “average” Ford employee.

Acknowledgement

I would like to acknowledge and dedicate this to my parents, Ashwini Kumar Bandekar and Anushri Bandekar. It would not have been possible without your continual support.

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List of Abbreviations

ANN	-	Artificial Neural Networks
ANOVA	-	Analysis of Variance
BMI	-	Body Mass Index
CSS	-	Continuous Severity Scale
FTOV	-	First Time Office Visit
LE	-	Lower Extremity
LWT	-	Lost Work Time
ML	-	Machine Learning
NJCHS	-	National Joint Committee on Health and Safety
NMQ	-	Nordic Musculoskeletal Questionnaire
OSHA	-	Occupational Safety and Health Administration
PT	-	Intensity of pain today
RPE	-	Rate of Perceived Physical Exertion
UAW	-	United Auto Workers
UE	-	Upper Extremity
VAS	-	Visual Analog Scale
WMSD	-	Work Related Musculoskeletal Disorder
WP	-	Worst Intensity of pain in the past year

1. Introduction

1.1 Background & Significance

Work-Related Musculoskeletal Disorders (WMSDs) are a leading cause of health problems and are responsible for lost-work days and a significant proportion of workplace injuries (Bernard et al., 1997; Silverstein & Clark, 2004). These include injuries affecting the muscles, tendons, ligaments, joints, nerves, and blood vessels (Nurmianto et al., 2015; Laura Punnett & Wegman, 2004a). WMSDs are not only the most common cause of severe long-term pain and disability amongst occupational workers worldwide (Westmorland & Williams, 2002) but, also severely impact quality of life and results into loss of mental wellbeing (Qutubuddin S M et al., n.d.). WMSD's carry a heavy economic burden in terms of direct costs such as workers' compensation (Leigh et al., 2001; Occupational Safety & Health (OSHA), n.d.). It is estimated that employers pay approximately one billion per week in workers' compensation costs alone (Occupational Safety & Health (OSHA), n.d.). Other indirect costs include lost productivity, costs associated with hiring, and training new employees (Bhattacharya, 2014; Xu et al., 2012).

From 1992 to 2010, WMSDs accounted for 29-35% of all occupational injuries and illnesses involving days away from work in private industries (AFL-CIO, n.d.; Bhattacharya, 2014). The aggregate impact of WMSDs is increasing rapidly with $54 billion in total direct costs in 1998 (Morse & Charles, 1998) to $ 796.3 billion in combined costs from 2009 to 2011 (Yelin et al., 1995, 2016).

The Automotive industry is characterized by assembly line type operations, which have been linked to several WMSDs and health risks (Guerreiro et al., 2017). There is a high prevalence of WMSDs in such assembly type of operations that include physical risk factors such as high repetition, increased work pace, high force, high speed of work, awkward posture, heavy physical activity, temperature, and vibration (Anita et al., 2014; da Costa & Vieira, 2010; Occhipinti & Colombini, 2016). Moreover, WMSDs occur at a higher rate in the automotive industry as compared to other manufacturing industries (Nur et al., 2014). Ergonomic interventions aimed to reduce these risk factors often involve changing or improving the job or the workstation (Draicchio et al., 2012; Drury et al., 2008) by providing better tools or making appropriate work process changes (Hakkanen et al., 1997). However, the interaction of the employee's personal characteristics with the physical risk factors associated with the job are often ignored.

1.2 Systematic Literature Review

Since the automotive manufacturing is a unique environment, a systematic literature review was conducted to identify existing studies that specifically explore the role of multiple risk factors and WMSDs. The scope of the review was limited to the automotive manufacturing sector and was conducted in the following steps:

1.2.1 Database Selection:

Ergonomic Abstracts, MEDLINE, and CINAHL were the databases selected to conduct the review.

1.2.2 Key-word Search:

The Search was conducted using keywords and logical/Boolean operators (AND/OR). Keywords used were intentionally kept broad to capture the maximum number of studies currently available. The final keyword search is as follows:

[*((Automotive)* ***OR*** *(Automotive Manufacturing)* ***OR*** *(Automotive Industry))*

AND

((Musculoskeletal disorders) ***OR*** *(Musculoskeletal pain)* ***OR*** *(Musculoskeletal injuries)* ***OR*** *(WMSD))****]***

1.2.3 Filters, Expanders and Limiters:

No study was excluded based on its year or the geography/location. The search was expanded to *"Apply equivalent subjects"* and *"Apply related words"* which resulted in **210** search results. The search was then filtered to only allow articles available in the English language which resulted in **144** search results. The search was further limited by source to published journals, journal articles and books, and studies conducted on humans. An exclude filter was also applied to avoid duplication between the CINAHL and MEDLINE databases which resulted in **102** search results. Further, exact duplicates were removed which resulted in **81** search results.

1.2.4 Title Review

A title review of the search results was conducted, and articles relating to *Road crash, Accidents, Performance of hand tools,* and *In-vehicle comfort* were removed which resulted into **61** articles.

1.2.5 Abstract Review

An abstract review was conducted following the title review, and articles related to *Workstation evaluation, Ergonomic tool application, Job-rotation strategies & effects,* and *Participatory ergonomics/exercise & stretching programs* were removed which resulted into **49** articles.

1.2.6 Paper Review

Forty-nine articles were reviewed following the abstract review, out of which papers that were related to *Simulation of tasks, Simulation of muscular adaptation to tasks, Effectiveness of a particular assembly jig/rig, Using Surface Electro-Myography, Surface thermography, Job-balancing,* and *Reliability analysis* were excluded which resulted into **11** articles. A summary of the articles identified after a systematic review is presented in *Table 1.*

Table 1: Systematic Literature Review Results

No	Author	Year	Title	Study Type	N	Body Part	Case Definition	Predictors/Influencers Identified	Conclusion	Affiliation
1	(L. Punnett et al., 2004a)	2004	Ergonomic stressors and upper extremity musculoskeletal disorders in automobile manufacturing: a one year follow up study.	Prospective	820	Upper Extremity	1) Discomfort & pain in the last year 2) At least 12 occasions of pain occurrence	1) Gender 2) Previous UE injury 3) Baseline physical examination 4) High job demand/low job control 5) High body mass index 6) Job change at follow up	Significant associations exist between UEMSDs and exposure to combined ergonomic stressors.	UAW Ford
2	(Werner et al., 2005b)	2005	Risk factors for visiting a medical department because of upper-extremity musculoskeletal disorders.	Prospective	279	Upper Extremity	FTOV	1) ACGIH TLV 2) Diagnoses of CTS 3) Diagnoses of Elbow tendonitis 4) Diabetes 5) Age > 40	Both ergonomic and past medical history are risk factors for an upper-extremity musculoskeletal disorder and suggests that there is a healthy worker or survivor effect among older workers.	UAW GM
3	(Gold et al., 2005)	2005	Digital vibration threshold testing and ergonomic stressors in automobile manufacturing workers: a cross-sectional assessment.	Cross sectional	1174	Head/Neck Shoulder Upper Extremity	Vibration Threshold measured by a modified Borgs scale (0-3)	1) High hand force 2) Floor vibration (WBV) 3) Posture 4) Physical effort 5) Contact Stress	Awkward postures, contact stress, and hand force factors may be associated with self-reported vibration thresholds	UAW Ford
4	(Werner et al., 2005a)	2005	Predictors of Persistent Elbow Tendonitis Among Auto Assembly Workers.	Prospective	45	Elbow	Medial or lateral epicondyle tenderness diagnosed through palpation	1) Repetition 2) Decision Authority 3) Peak wrist flexion/extension 4) Age	Older workers with jobs requiring more repetition and awkward wrist postures, and less decision authority were less likely to have resolution of their elbow tendonitis.	UAW GM
5	(Carnide et al., 2006)	2006	Interaction of biomechanical and morphological factors on shoulder workload in industrial paint work.	Cross sectional	29	Shoulder Hands & Wrist	Pain	1) Biomechanical 2) Morphological (Endo, Ecto, Meso)	Pain was the only estimator that could predict the risk of occurrence of musculoskeletal symptoms. Multifactor linear analysis showed that some linear and combined anthropometric characteristics could be associated to a higher workload on the shoulders and upper limbs.	-
6	(Gold et al., 2006)	2006	Pressure pain thresholds and musculoskeletal morbidity in automobile manufacturing workers.	Prospective	519	Upper Extremity	Upper extremity pressure pain thresholds (Identified by applying pressure applied on skin)	1) Gender 2) Grip strength 3) Pain severity 4) Functional impairment score	Pain Pressure Thresholds (PPTs) were associated with signs and symptoms of UEMSDs, after adjusting for gender, age and grip strength.	UAW Chrysler

Table 2: Systematic Literature Review Results (continued)

7	(el ahrache & Imbeau, 2009)	2009	Comparison of rest allowance models for static muscular work.	Prospective	7	Shoulder		Rest allowance	Shoulder requires more rest than other muscle groups	-
8	(F.A. Seamana, W.J. Alberta,∗, N.R.E. Weldona, 2010)	2010	Biomechanical shoulder loads and postures in light automotive assembly workers: Comparison between shoulder pain/no pain groups.	Cross sectional	79	Shoulder	Pain	1) Shoulder posture 2) Peak load 3) Cumulative load	Individuals working some jobs may be at an increased risk of developing MSDs based on the amount of time spent in flexed postures, as well as the peak flexion moment acting on the shoulder.	-
9	(Grobler, 2013)	2013	Self-reported work-related musculoskeletal injuries and isometric handgrip strength.	Cross sectional	206	Any	Pain in past 7 days	Weak hand grip (did not predict)	Weak handgrip did not predict increased risk of od musculoskeletal injuries.	-
10	(Valirad et al., 2015)	2015	Interaction of Physical Exposures and Occupational Factors on Sickness Absence in Automotive Industry Workers.	Cross sectional	758	Any	Days absent due to sickness	1) Blue collar jobs & Shift work 2) Bending 3) Twisting 4) Lifting 5) Vibration	Identifying controllable factors of sickness absence and trying to prevent and modify them such as compliance of ergonomic principals to decrease physical can be effective in reducing sickness absence.	-
11	(Hausmanninger et al., 2019)	2018	Hand as hammer: A comprehensive review of biomechanical studies related to occupational hand strikes.	Review		Arm & Wrist	-	1) Peak Force 2) Acceleration 3) Impulse 4) Use of gloves	The higher the repetition rate of strikes, the smaller the subjectively acceptable peak force and impulse. Ulnar posture shows increased peak stresses on the target, a higher effective mass, as well as smaller peak accelerations and impulses during hand impact. High acceleration values during palm strikes should be regarded as a risk factor for progressing stress in hand structures. Larger skinfold thickness or the use of gloves can reduce stress in tissues of the hand and wrist by decreased maximum accelerations	-

1.3 State of Art

Several studies conducted in a manufacturing/industrial setting have investigated the role of individual risk factors such as gender (Maj et al., 1999), age (Villanueva & Garcia, 2011), Body Mass Index (BMI) (Tsai et al., 1992b), smoking status (Tsai et al., 1992a), anthropometry (Smedley et al., 1995), and years of experience of work, as well as presence of pre-diagnosed medical conditions (da Costa & Vieira, 2010) to predict WMSDs. Further, several epidemiological studies have also explored the role of psychosocial factors such as monotonous work, lack of job control, time pressure and poor employee-supervisor relationships as risk factors to develop WMSDs (Èns et al., 2001). The causes for developing a WMSD are multifactorial, however, many studies focus on only one or two risk factors at a time and typically only on one body part or region. For example, (Govindu & Babski-Reeves, 2014) studied the effects of personal, psychosocial, and occupational factors only on low-back pain severity. Bao et al (Bao et al., 2016)studied the relationships between job organizational factors, biomechanical and psychosocial factors and WMSDs. (Gerr, Fethke, Merlino, et al., 2014) published two separate studies: first on the effects of physical risk factors and later, effects of psychosocial stress and work-organizational factors on WMSDs (Gerr, Fethke, Anton, et al., 2014).

The 11 articles identified in the literature review, did analyze the role of some risk factors on individual body parts, but none of the articles presented a holistic perspective by addressing multiple risk factors across all anatomical sites.

The exact pathogenesis and etiology of developing a WMSD are multifactorial and involve a complex combination of physical, individual, and psychosocial risk factors,

all of which should be addressed for an effective ergonomic intervention (Boocock et al., 2009; da Costa & Vieira, 2010). This study not only considers the risks associated with performing a repetitive job but also considers risk factors related to the employees themselves. The results from this study can potentially enable industry to more accurately predict the risks of developing an injury on a body segment for a specific employee, working on a particular job. Moreover, applying advanced data analysis tools such as Machine Learning (Cimmino et al., 2011; Harden et al., 2007; Harrington et al., 1998; Sluiter' et al., n.d.) to develop a holistic predictive model in the automotive sector could prove to be a breakthrough in the field of applied ergonomics. Data related to the personal characteristic of the employee were collected using a Nordic-style musculoskeletal questionnaire. The Nordic Musculoskeletal Questionnaire has been shown to be an effective, sensitive and repeatable tool to assess personal discomfort (Cimmino et al., 2011; Harden et al., 2007; Harrington et al., 1998; Sluiter' et al., n.d.). Additionally, this study has potential to further validate the Nordic Musculoskeletal Questionnaire and form a solid foundation for a database that can be used to test future hypotheses formulated by researchers in the field of epidemiology and injury prevention.

1.4 Original Study

A request for proposal was offered by the United Auto Workers (UAW)-Ford National Joint Committee on Health and Safety (NJCHS), which was comprised of members from UAW and Ford Motor Company to enable the development of a unique risk evaluation tool that could be widely used in Ford Motor Company's manufacturing facilities. The University of Utah (UU) and the University of South Florida (USF) submitted a joint proposal that was accepted by the UAW-Ford NJCHS.

A cross-sectional study was performed by an interdisciplinary team of researchers from UU and USF for 1,016 production employees (*735 males, 274 females*) across six manufacturing plants. The plants included in the study were: (1) a small-component production plant in Rawsonville, Michigan, (2) a vehicle assembly plant in Louisville, Kentucky, (3) a heater and air-conditioning component plant in Plymouth, Michigan, (4) an engine assembly plant in Lima, Ohio, (5) a transmission assembly plant in Livonia, Michigan, and (6) a metal Stamping plant in Woodhaven, Michigan. Employees ranged from 20 to 70 years of age (*mean = 41.54, SD = 10.94*); additional demographic information is presented in *Table 1*. The plants were selected to present a representative cross-section of Ford Motor Company operations and to allow results to be generalized across Ford.

Subjects (employees) were chosen randomly in accordance to the Institutional Review Board (IRB) requirements set forth by UU and USF. All subjects willingly agreed to participate in this study without any coercion or financial incentives, and no one was excluded based on their gender, race, ethnicity or age. Data were stored in an anonymized and aggregated format with no personal identifiers. The subjects were entered as a four digit "Subject ID"; likewise, jobs were assigned separate four digit "Job IDs". *Table 1* describes the demographic characteristics of the subjects in the original study. The demographic characteristics presented are gender, age, Body Mass Index (BMI), years of experience, smoking status, presence of pre-diagnosed medical conditions, job shift worked by the employees and the distribution of subjects across the six sites. Significant differences were found in the demographic characteristics of employees across the difference sites and are discussed below.

Table 2: Demographic Characteristics of Employees (Subjects)

Demographic Characteristics	**Total N = 1,016** N(%)
Gender *(Valid n = 1,009)*	
Male	735 (72.3)
Female	274 (27)
Age, years *(Valid n = 1,016)*	
20 - 30	232 (22.8)
31 - 40	239 (23.5)
41 - 50	324 (31.9)
51 - 60	176 (17.3)
> 60	45 (4.4)
BMI *(Valid n = 1,001)*	
Normal	302 (29.7)
Overweight	436 (42.9)
Obese	263 (25.9)
Experience *(Valid n = 1,016)*	
< 3 years	607 (59.7)
3 - 5 years	243 (23.9)
6 - 10 years	97 (9.5)
> 10 years	69 (6.8)
Smoking *(Valid n = 1,016)*	
Current Smoker	367 (36.1)
Ex-Smoker	241 (23.7)
Never Smoked	408 (40.2)
Comorbidities/pre-existing conditions *(Valid n = 1,016)*	
No	750 (73.8)
Yes	266 (26.2)
Job Shift *(Valid n = 1,013)*	
Day Shift	579 (57)
Swing Shift	434 (42.7)
Site *(Valid n = 1,016)*	
Rawsonville, MI (Small Parts)	120 (11.8)
Louisville, KY (Final Assembly)	245 (24.1)
Plymouth, MI (HVAC)	152 (15)
Lima, OH (Engine)	188 (18.5)
Livonia, MI (Transmission)	148 (14.6)
Woodhaven, MI (Stamping)	163 (16)

1.5 Site Differences

Multiple statistical analyses are used to determine differences in subject demographics by gender, age, BMI, and experience.

1.5.1 Gender:

Chi-square test is used to determine if there are differences in gender across the six manufacturing facilities.

Table 3: Site-wise Gender Distribution

Site	Gender		Total
	Male	Female	
Small Parts	88	32	120
Final Assembly	175	67	242
HVAC	91	59	150
Engine	162	25	187
Transmission	114	34	148
Stamping	105	57	162
Total	735	274	1009

Table 4: Site Differences - Gender: Chi-Square Test Results

	Value	df	Significance
Pearson Chi-Square	35.851	5	**0.001**
Likelihood Ratio	37.560	5	0.000
Linear-by-Linear Association	0.001	1	0.974
N of Valid Cases	1009		

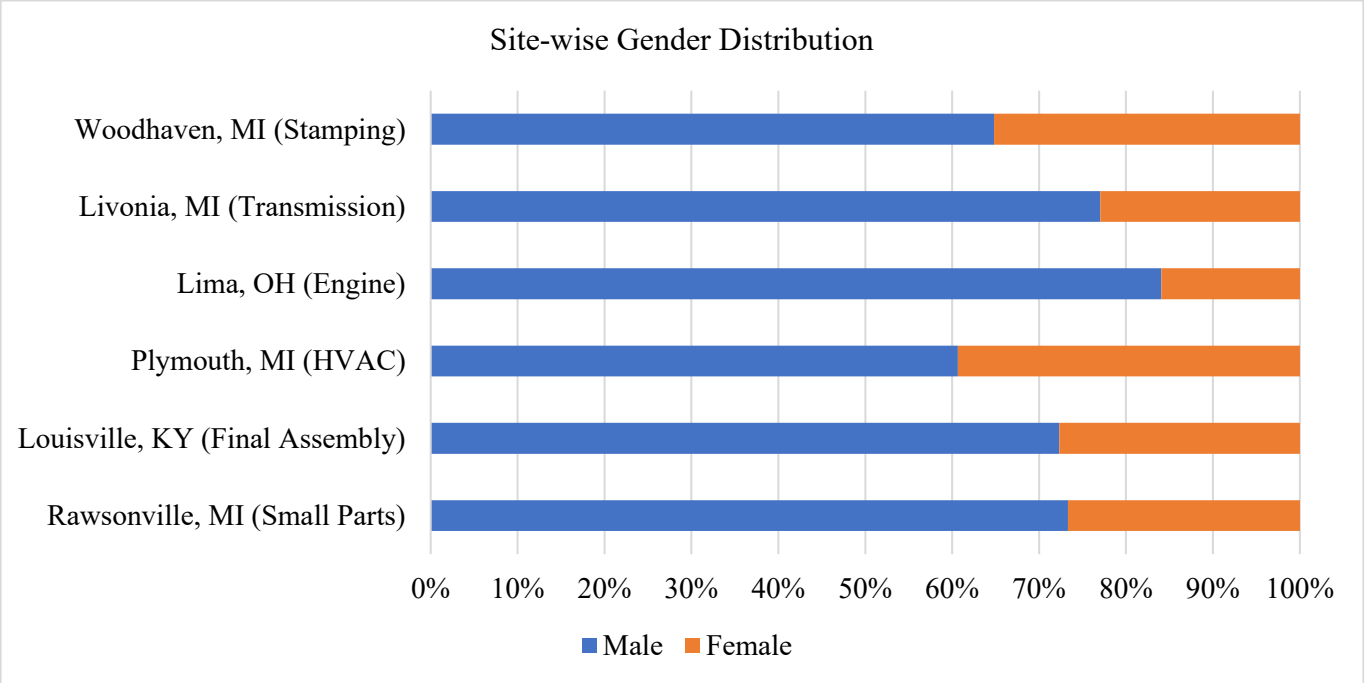

Figure 1: Site-wise Gender Distribution (%)

1.5.2 BMI:

Analysis of Variance (ANOVA) is used to determine differences in BMI across the six manufacturing facilities.

Table 5: Site-wise Differences in BMI

Site	N	Mean	Std. Deviation	Min	Max
Small Parts	120.00	28.75	5.40	18.30	54.80
Final Assembly	242.00	26.37	3.94	17.80	42.00
HVAC	149.00	27.41	4.64	16.10	41.80
Engine	185.00	28.16	4.50	17.00	43.80
Transmission	146.00	28.47	5.01	16.00	45.40
Stamping	159.00	27.09	4.95	18.40	44.60
Total	1001.00	27.56	4.73	16.00	54.80

Table 6: Site-wise Differences in BMI - ANOVA Result

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	738.24	5.00	147.64	6.78	**0.001**
Within Groups	21655.17	995.00	21.76		
Total	22393.41	1000.00			

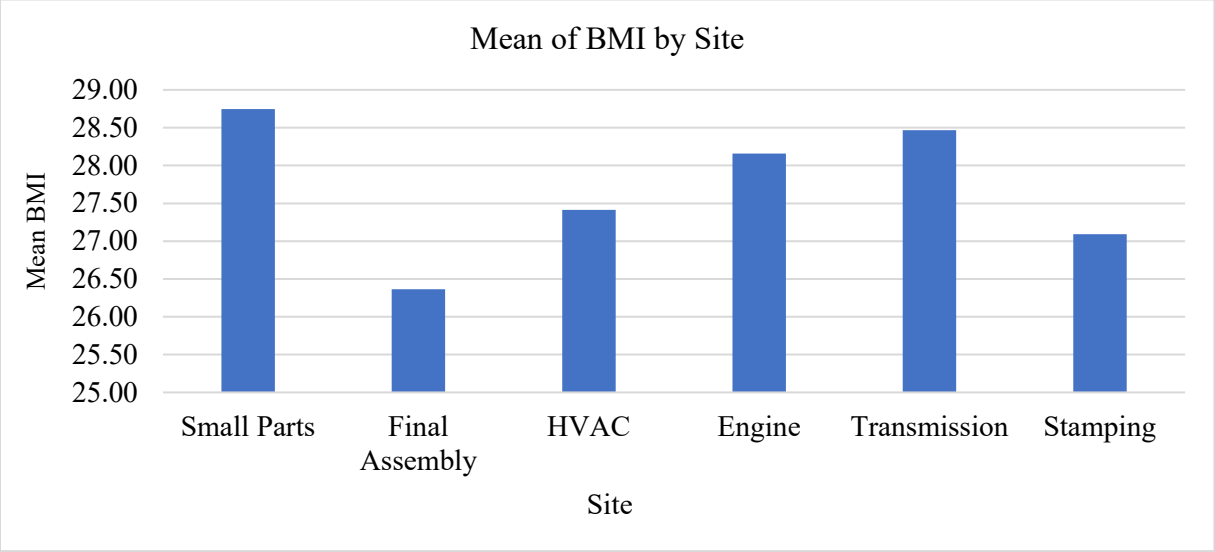

Figure 2: Site-wise Differences in BMI

1.5.3 Age:

ANOVA is used to determine differences in age across the six manufacturing facilities.

Table 7: Site-wise Differences in Age

Sites	N	Mean	Std. Dev	Min	Max
Small Parts	120.00	41.99	11.45	21.38	68.25
Final Assembly	245.00	37.48	8.31	21.52	64.35
HVAC	150.00	38.82	9.89	20.26	65.44
Engine	188.00	50.60	6.97	22.68	67.31
Transmission	146.00	45.85	10.58	23.25	67.00
Stamping	162.00	35.46	10.97	21.00	70.86
Total	1011.00	41.54	10.95	20.26	70.86

Table 8: Site-wise Differences in Age - ANOVA Results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	29309.89	5	5861.97	64.25	**0.001**
Within Groups	91686.72	1005	91.23		
Total	120996.6	1010			

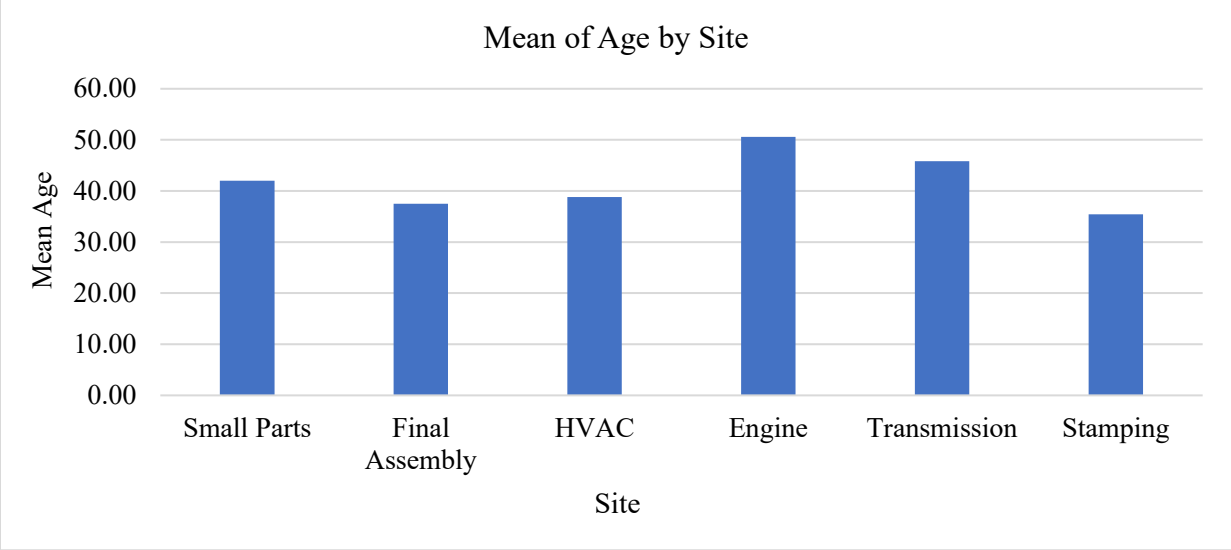

Figure 3: Site-wise Differences in Age

1.5.4 Experience:

ANOVA is used to determine differences in age across the sic manufacturing facilities.

Table 9: Site-wise Differences in Experience (years)

Site	N	Mean	Std. Dev	Min	Max
Small Parts	120.00	3.86	5.50	0.00	35.00
Final Assembly	245.00	3.48	3.47	0.04	25.00
HVAC	152.00	1.90	2.47	0.00	14.00
Engine	188.00	4.90	5.96	0.00	39.00
Transmission	148.00	3.72	3.88	0.01	16.00
Stamping	163.00	1.77	2.35	0.04	20.00
Total	1016.00	3.31	4.26	0.00	39.00

Table 10: Site-wise Differences in Experience (years) - ANOVA Results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1232.9	5	246.58	14.47	**0.001**
Within Groups	17201.03	1010	17.03		
Total	18433.94	1015			

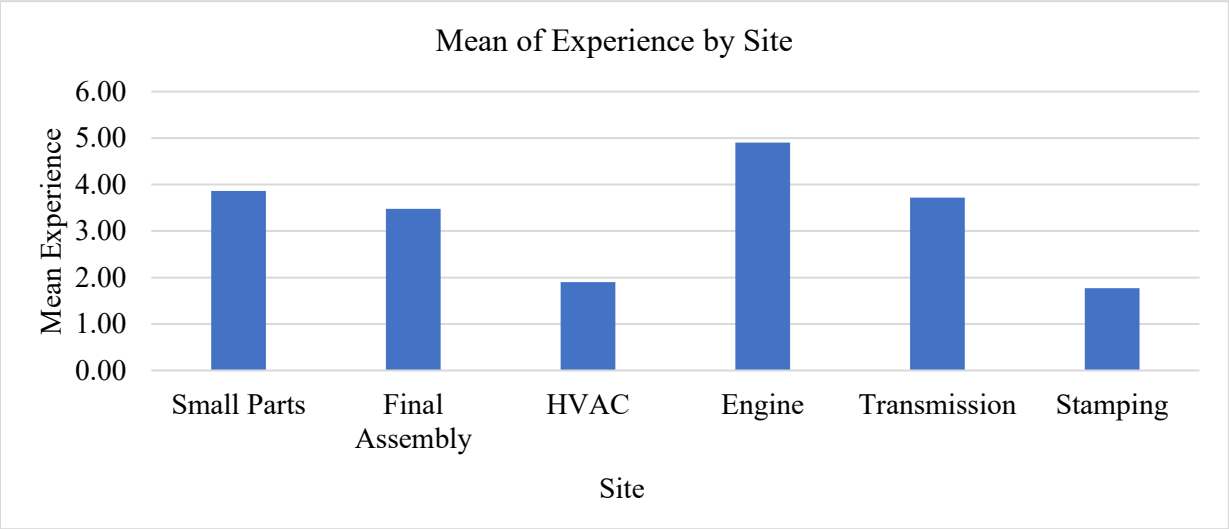

Figure 4: Site-wise Differences in Experience (years)

1.6 Types of Data Collected

Three types of data were collected:

(1) Ergonomic Data & Video – Two-person teams were present at each facility to collect data: they completed a minimum question set form [*Appendix 4*] while observing and video-taping the subjects who were carrying out their respective tasks. These data can be broadly classified as: a) Job Requirements, b) Ergo analyses, and c) Ergo assessment tools. This consisted of job-specific data such as number of repetitions, exposure to vibration, etc., data related to the general working environment such as light conditions, access to floor mats, exposure to background noise, etc., and elements of various ergonomic assessment tools that were commonly used at the time of data collection.

The purpose of the original study was to compare several ergonomic assessment tools and identify the most predictive elements from those tools to create a unique risk evaluation and surveillance tool that best suited operations and employees at the Ford Motor Company's manufacturing facilities. The tools used for this purpose were: a) The OSHA Checklist (OSHA, 1995), b) The Strain Index (Moore & Garg, 1995), c) Rapid Upper Limb Assessment (RULA) (Mcatamney & Corlett, 1993), d) Rodgers' Model (Rodgers, 1992), e) ALPHA/BETA Model (Ford Motor Company, 1994), f) Liberty Mutual Psychophysical Tables ("Snook Tables") (Snook & Ciriello, 1991), and g) Expert Opinion (Expert opinion of the on-site field ergonomists collecting the data).

(2) Structured Interview Data – Subjects were individually interviewed by Occupational Health Nurses (OHNs) and Occupational Therapists (OTs) with a self-

administered Nordic-style questionnaire for symptoms [*Appendix 2*]. This style of questionnaire has been widely used and accepted to evaluate WMSDs in the workplace (Cimmino et al., 2011; Harden et al., 2007; Harrington et al., 1998; Sluiter' et al., n.d.). The subjects were asked general questions regarding their job history followed by a front and back body map where the subjects were instructed to shade all areas of discomfort. The OHNs and OTs then followed this by completing a detailed structured interview regarding outcomes for all body regions (Head/Neck, Shoulder, Elbow, Hand/Wrist, Low-Back, Hip, Knee, and Ankle/Feet) indicated as having discomfort.

(3) Medical Data – A cursory medical exam was conducted by Occupational Medicine (OM) physicians on each subject. The OM physicians were blinded to the structured interviews conducted by the OHNs and OTs and conducted this examination on the subjects across the same body regions (Head/Neck, Shoulder, Elbow, Hand/Wrist, Low-Back, Hip, Knee, and Ankle/Feet). This Medical form [*Appendix 3*] contained information on tenderness, physical abnormalities, decreased range of motion (ROM), etc. Physician "diagnoses" were imputed from the medical data based on combinations of physicians' findings. It should be noted that OM doctors were also blinded to patient history and were instructed specifically not to ask the subjects about past injuries or prior diagnoses, so as not to be biased by this information. The outcomes from the structured interview data will be compared to OM diagnoses allowing an analysis of the congruence of these health outcome measures.

Chapter 2: Pain & Discomfort – Prevalence, Characteristics, Consequences, and Risk factors

2.1 Introduction

The automotive industry and OEM's (Original Equipment Manufacturers) have a rapid production schedule which generally consists of highly repetitive assembly operations and tasks due to which contribute to a high prevalence of WMSDs (Anita et al., 2014). Literature suggests that WMSDs also occur at a higher rate in the automotive industry as compared to other manufacturing industries (Nur et al., 2014).

The purpose of this study is to identify the prevalence of musculoskeletal pain and discomfort among the subjects in the automotive database, followed by the characteristics and consequences of musculoskeletal pain and discomfort. This study also identifies preliminary risk factors associated with musculoskeletal pain and discomfort.

However, before beginning analyses, it is important to setup the database in a manner where the unit of exposure is the employee/subject.

2.2 Methods

2.2.1 Database Setup

The structured interview dataset consisted of questions related to the onset of discomfort/pain, intensity of pain, number of episodes and duration of pain, and related consequences such as First Time Office Visit (FTOV) and treatment seeking patterns, placement on restricted or "Light" duty, and Lost Worktime (LWT) due to pain. For the initial analyses, the simple presence of discomfort and pain will be used to classify subjects into "Cases" (Pain = YES) and "Controls"

(Pain = NO). Later, a more complex and continuous case definition that takes multiple factors into consideration, such as “pain level”, will be developed.

This study consists of 1,016 subjects performing 678 jobs, therefore, there were some jobs performed by multiple employees often from different shifts, as can be seen from *Table 11*. Since the overall theme of this research is the “personalization” of risk to specific subjects, the unit of exposure is the subject (employee) and not the job. This is in contrast to the original study, where the UAW-Ford NJCHS was specifically looking for the risk of the job to the “average” Ford employee (i.e., unit of analysis was the job). As a result, personal characteristics were *not* considered in the original study, and there remains a vast amount of potentially explanatory data that have, heretofore, been unexplored. The original study, with an intent to avoid potential discrimination based on individual differences, considered only physical ergonomic risk factors associated with each job. This dissertation breaks new ground by combining this rich set of personal characteristic data with the physical demands of the job itself to form a more complete risk assessment model. In addition, it will simultaneously consider multiple body parts and explore the impact of co-morbidities (i.e., multiple health conditions and injuries to other body parts).

Multiple data collection forms were used to collect data in the original study, some with the Subject IDs as the reference and some with the Job IDs as the reference. The Subject ID and Job ID were matched as seen in *Table 12* to map personal outcomes with the job demands for all body regions in two formats:

Table 11: Subject ID to Job ID

Subject ID	JOB ID
1510	1001
1543	1001
1509	1002
1518	1002
7520	1003
7523	1003

Table 12: Job ID to Subject ID

Job ID	Subject ID	
1001	1510	1543
1002	1509	1518
1003	7520	7523

Information from the different data collection forms was merged into a single spreadsheet for all body regions to facilitate ease of analysis. A preview of the spreadsheet can be seen in *Table 13.*

Table 13: Preview of spreadsheet format

Subject ID	Job ID	Personal Characteristics	Interview Form	Medical Form	Job Requirements Form	Ergo Analysis Form	Ergo Tools Assessment
1510	1001						

The unit of exposure in the original study was the job, *not the subject*, and all job-related information was collected with the Job ID as the reference. Further, each job was broken down into tasks (up to 7 tasks) and each task was analyzed independently. Analysis was performed at the job level; each job could have up to 7 tasks aggregated to a job level risk. It was possible that more than 1 employee performed a given job. Since the unit of exposure in the current study is the subject (employee), it was necessary to

correctly map the risks and assessments of all relevant job tasks to the individual (employee/subject). This was accomplished by aggregating all job-related variables and mapping them back to the Subject ID. The logic is illustrated as follows:

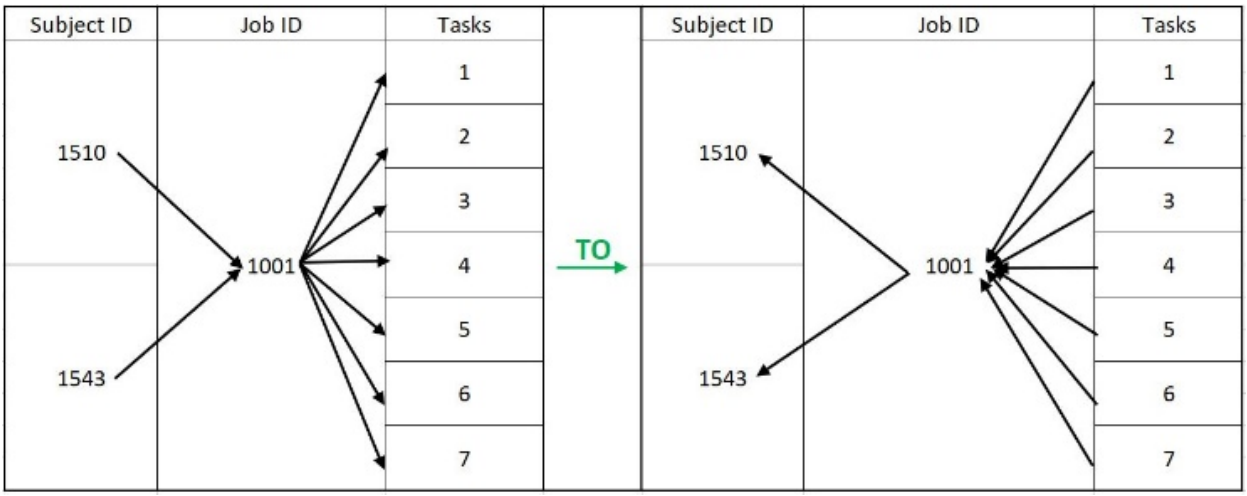

Figure 5: Conversion of Job-level data to Subject-level data

The original paper-based data collection forms were scanned using Teleform (Cardiff Software 1998), a software that provided an output with short abbreviations for each variable. Further the output lacked details about the nature of the variable (continuous, categorical, ordinal, etc.) and information within the values in a variable. The current database setup provides the end user with; a) Source of the variable , b) Name of the variable, c) Type of variable, and d) The meaning of each value within a variable.

Due to the absence of a centralized and a unified dataset, many factors were not considered in the original study, for example, the medical data was never used. The current database setup maintains the subject ID (employee) as a reference and provides all variable across all data collection form in a single easy to use spreadsheet.

2.2.2 Prevalence

Data were collected for eight body regions (Head/Neck, Shoulder, Elbow, Hand/Wrist, Low back, Hip, Knee, and Ankle/Feet). The prevalence for each body part affected was calculated using the structured interview forms [*Appendix 2*]. Prevalence was considered if the subject (employee) indicated 'Yes' to the question, "*Have you experienced musculoskeletal pain or discomfort of your _[body region]_ during the past year*" (first question asked by the OHNs and the OTs). Percentages are calculated for each body region and represented in *Figure 6.*

2.2.3 Characteristics

The structured interview form asked questions regarding the characteristics *(Table 13)* of pain and discomfort experienced by the subjects. These questions included:

a) **Type of pain** *(Which of the following word(s) best describe your musculoskeletal symptom?)* – 15 check boxes were provided to the OHNs and OTs that contained specific descriptors of pain such as; *Aching, Pain, Weakness, Burning, Swelling, Knots, Cramping, Spasms, Nocturnal Discomfort, Loss of color, Stiffness, Numbness, Tingling, Other, and None.* Percentages are calculated for each pain descriptor.

b) **Number of episodes of pain in the last year** *(How many separate episodes have you experienced in the past year?)* – The OHNs and OTs asked for a

number to be provided by the subjects. Mean and standard deviation are calculated.

c) **Duration of the typical episode of pain** *(How long does the typical episode last?)* – eight checkboxes were provided with value ranging from *"< 1hr"* to *"> 3months"*. Presence of "Continuous pain" was designated by the OHNs and OTs indicating a 365 on number of episodes **AND** Duration greater than, equal to one day. Percentages are calculated for duration of the episodes and presence of continuous pain.

d) **Recent pain** *(Have your experienced this symptom in the last 7 days?)* – A *'Yes'* and *'No'* checkbox was provided to the OHNs and OTs. Percentages are calculated.

e) **Intensity of symptom today –** The subjects were asked to draw a vertical line that intersects a 100-mm horizontal Visual-Analog Scale (VAS) ranging from *"None"* to *"Unbearable"*. Mean and standard deviation are calculated.

f) **Intensity of the symptom when it is the worst -** The subjects were asked to draw a vertical line that intersects a 100-mm horizontal VAS ranging from *"None"* to *"Unbearable"*. Mean and standard deviation are calculated.

For 'Intensity of symptom today' and 'Intensity of the symptom when it is the worst', the researchers went back and calculated the numerical value of the subject's (employee's) intensity rating by a numbered ruler, rounded to the nearest digit. The VAS was 100-mm in length range of 0 – 100, with 0 being labelled as *"None"* and 100 being labelled as *"Unbearable"*. A box and whisker plot consisting of range, quartiles and average of the intensities of pain is created

for ‘Intensity of symptom today’ (Figure 8), and ‘Intensity of the symptom when it is the worst’ (Figure 9) to visualize the distribution of “pain scores”.

Table 14: Pain & Discomfort - Prevalence & Characteristics

Pain & Discomfort	N	Head/Neck		Shoulder		Elbow		Hand/Wrist		Low Back		Hips		Knee		Ankle/Feet	
		169		340		191		440		357		64		177		171	
Intensity of Pain Today, *M* ± *SD*		27.72 ± 22.6		23.7 ± 23.6		25.7 ± 23.7		27.5 ± 24.2		25.7 ± 25		20.9 ± 22.5		23.2 ± 24.4		30.2 ± 27.2	
Intensity of Worst Pain, *M* ± *SD*		73.6 ± 18.6		69.8 ± 20.9		67.7 ± 20.6		70.6 ± 20.5		76 ± 20.3		72.9 ± 22.9		67.3 ± 22.7		73.6 ± 23.2	
Separate Episodes of Pain in Last Year, *M* ± *SD*		177.3 ± 161.5		177.9 ± 163.7		170 ± 160.8		192.9 ± 163.2		151.7 ± 161		138.9 ± 156		173 ± 160.2		208 ± 157.8	
Pain in the last 7 Days, n / %		126	74.6%	244	71.8%	128	67.0%	324	73.6%	237	66.4%	42	65.6%	127	71.8%	138	80.7%
Typical Duration of Episode n / %	< 1 Hour	9	5.3%	15	4.4%	10	5.2%	33	7.5%	18	5.0%	6	9.4%	11	6.2%	7	4.1%
	1 Hour	11	6.5%	16	4.7%	10	5.2%	29	6.6%	20	5.6%	4	6.3%	8	4.5%	6	3.5%
	1 Day	46	27.2%	88	25.9%	52	27.2%	109	24.8%	103	28.9%	20	31.3%	46	26.0%	55	32.2%
	1 Week	35	20.7%	52	15.3%	28	14.7%	45	10.2%	66	18.5%	11	17.2%	29	16.4%	16	9.4%
	1 Month	3	1.8%	14	4.1%	13	6.8%	22	5.0%	23	6.4%	3	4.7%	4	2.3%	3	1.8%
	2 Months	2	1.2%	4	1.2%	4	2.1%	3	0.7%	3	0.8%	1	1.6%	3	1.7%	2	1.2%
	3 Months	0	0.0%	3	0.9%	1	0.5%	1	0.2%	1	0.3%	0	0.0%	1	0.6%	0	0.0%
	> 3 Months	65	38.5%	144	42.4%	73	38.2%	198	45.0%	125	35.0%	19	29.7%	75	42.4%	82	48.0%
Continuous Pain (24x7x365), n / %		62	36.7%	134	39.4%	68	35.6%	184	41.8%	116	32.5%	18	28.1%	66	37.3%	78	45.6%
Most Problematic symptom of Pain n /%	Aching	38	22.5%	125	36.8%	52	27.2%	113	25.7%	112	31.4%	17	26.6%	51	28.8%	63	36.8%
	General	43	25.4%	95	27.9%	80	41.9%	108	24.5%	126	35.3%	29	45.3%	66	37.3%	66	38.6%
	Weakness	1	0.6%	6	1.8%	10	5.2%	14	3.2%	1	0.3%	0	0.0%	10	5.6%	5	2.9%
	Burning	10	5.9%	25	7.4%	12	6.3%	10	2.3%	8	2.2%	2	3.1%	8	4.5%	13	7.6%
	Swelling	0	0.0%	1	0.3%	3	1.6%	12	2.7%	0	0.0%	0	0.0%	4	2.3%	5	2.9%
	Knots	3	1.8%	9	2.6%	0	0.0%	2	0.5%	4	1.1%	0	0.0%	1	0.6%	0	0.0%
	Cramping	2	1.2%	4	1.2%	4	2.1%	25	5.7%	8	2.2%	1	1.6%	4	2.3%	2	1.2%
	Spasms	7	4.1%	10	2.9%	1	0.5%	9	2.0%	26	7.3%	3	4.7%	2	1.1%	0	0.0%
	Nocturnal Discomfort	5	3.0%	11	3.2%	3	1.6%	18	4.1%	10	2.8%	3	4.7%	6	3.4%	0	0.0%
	Loss of Color	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	Stiffness	50	29.6%	32	9.4%	5	2.6%	34	7.7%	51	14.3%	3	4.7%	18	10.2%	10	5.8%
	Numbness	0	0.0%	2	0.6%	5	2.6%	40	9.1%	0	0.0%	2	3.1%	0	0.0%	3	1.8%
	Tingling	4	2.4%	2	0.6%	6	3.1%	34	7.7%	2	0.6%	0	0.0%	2	1.1%	3	1.8%
	Other	6	3.6%	17	5.0%	10	5.2%	21	4.8%	9	2.5%	3	4.7%	5	2.8%	1	0.6%
	None	0	0.0%	1	0.3%	0	0.0%	0	0.0%	0	0.0%	1	1.6%	0	0.0%	0	0.0%

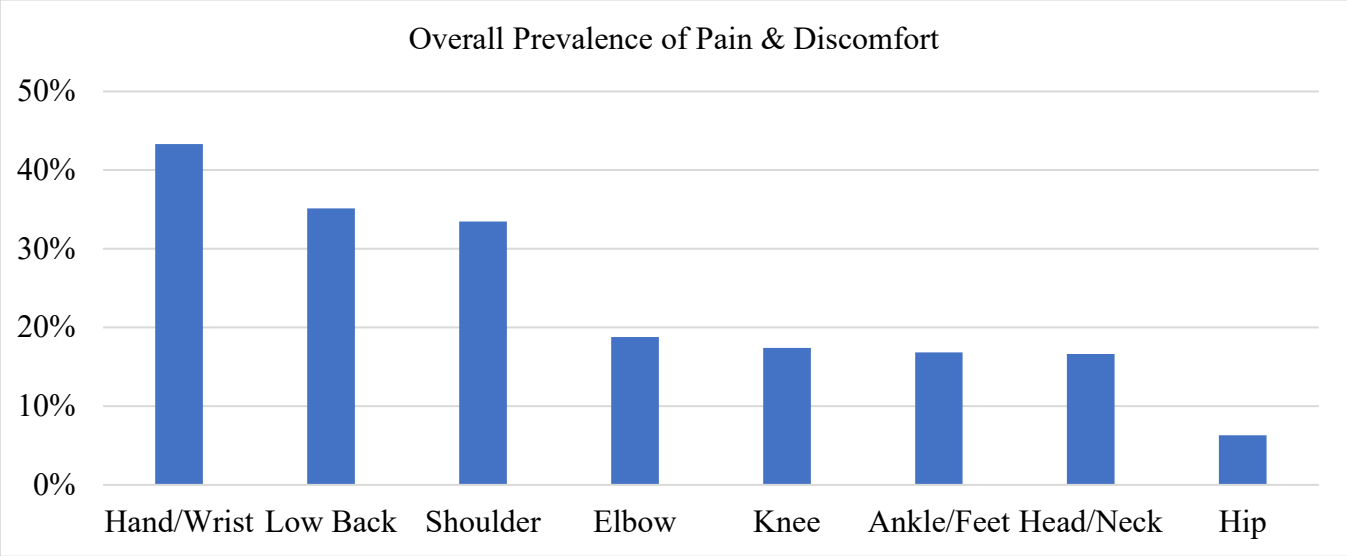

Figure 6: Overall Prevalence of Pain & Discomfort (%)

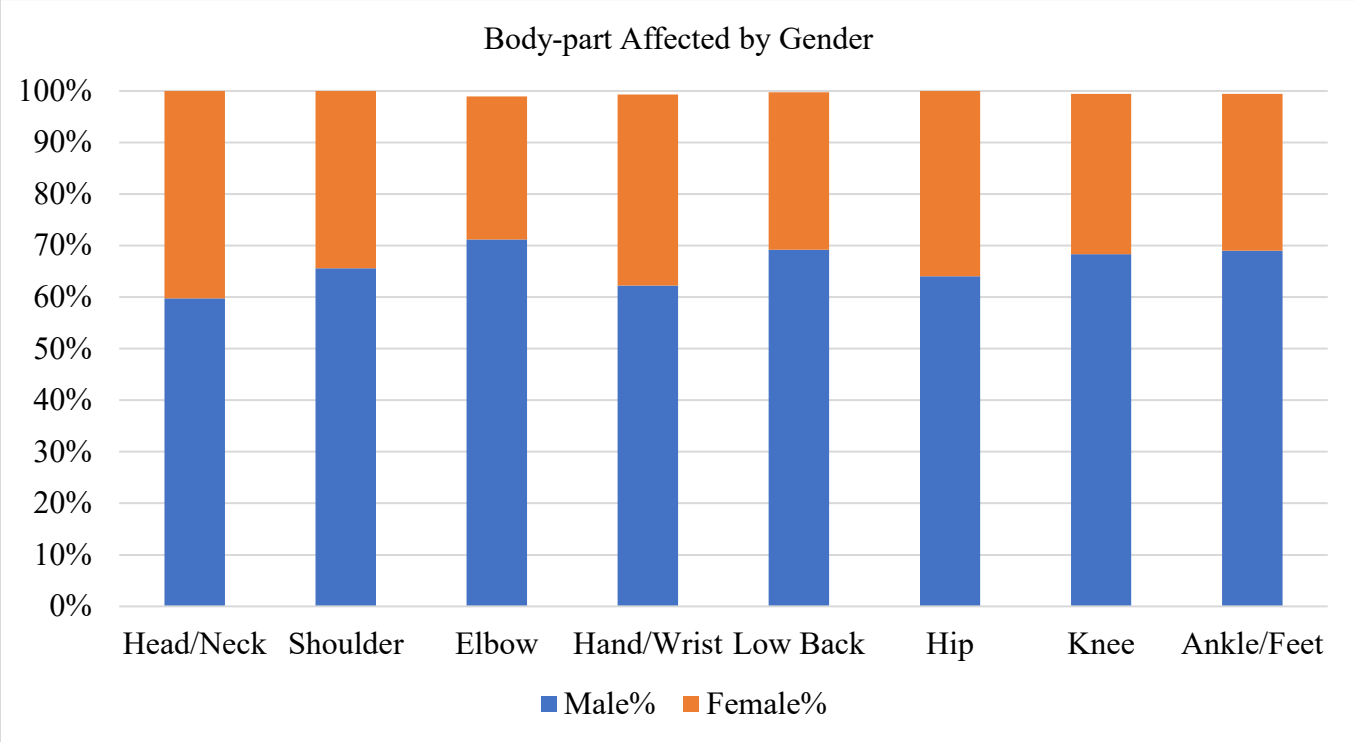

Figure 7: Body-part Affected by Gender (%)

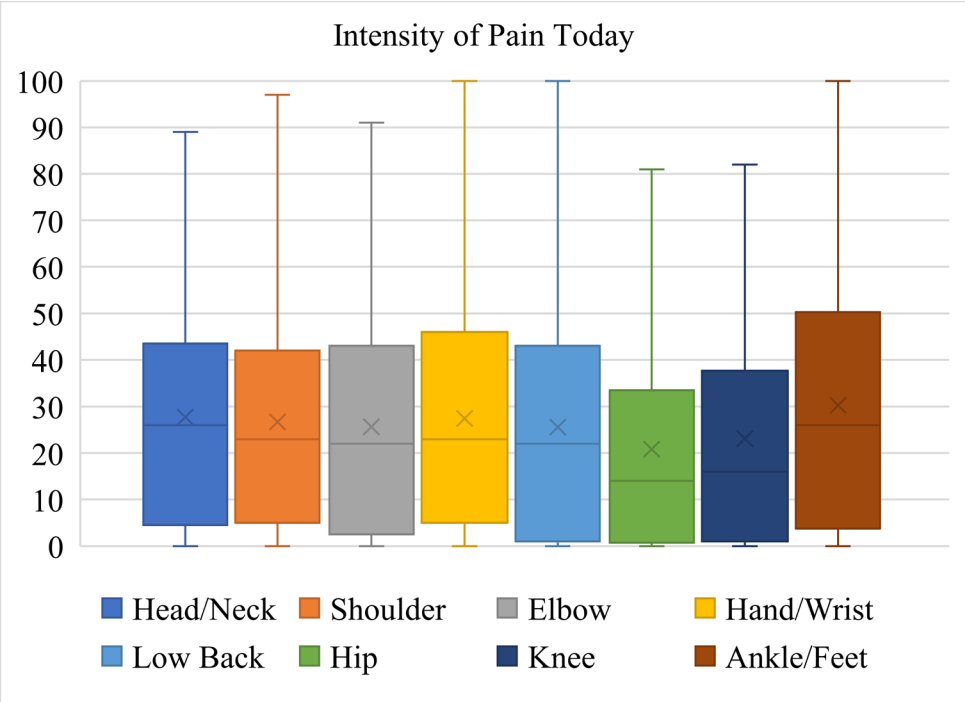

Figure 9: Distribution of Intensity of 'Pain Today' by Body-part

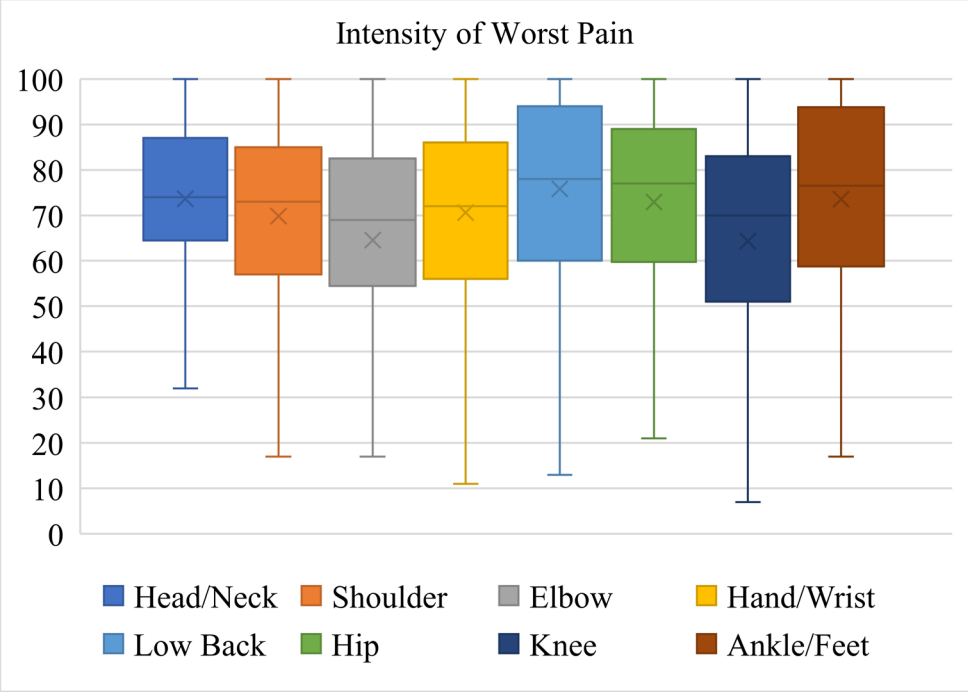

Figure 8: Distribution of Intensity of 'Worst Pain' by Body-part

2.2.4 Consequences

In this study, consequences are defined as the actions taken or experienced by the employee because of pain and discomfort. The structured interview form asked questions regarding the consequences of pain. These questions include:

a) **Clinic Visits** *(Have you received treatment for this symptom?)* – If the subject answered 'Yes' to this question, the subject was further asked if the visits were to the in-house plant clinic or an outside clinic and the number of visits in the past year. If the subject answered 'No', a follow-up question was asked to get a reason for not seeking treatment. Mean and standard deviation are calculated for each, number of visits to the plant clinic and number of visits to the outside clinic for all body regions.

b) **Restricted Duty** *(Since working on the current job, how many days have you been on restricted/light duty due to this musculoskeletal symptom?)* – Number of days answered by the subject were further categorized into *Less than seven days, 7 – 30 days, 31 – 60 days, 61 – 90 days,* and *Over 90 days.* Percentages are calculated.

c) **Lost Time** *(Since working on the current job, how much lost work time have you taken due to this musculoskeletal symptom?)* - Number of days answered by the subject were further categorized into *Less than 7 days, 7 – 30 days, 31 – 60 days, 61 – 90 days,* and *Over 90 days.* Percentages are calculated.

For 'Restricted Duty' and 'Lost Time', categories are also created as each incremental category is an order of magnitude more severe than the previous one.

Table 15: Pain & Discomfort - Consequences

Pain & Discomfort		**Head/Neck**		**Shoulder**		**Elbow**		**Hand/Wrist**		**Low Back**		**Hips**		**Knee**		**Ankle/Feet**	
		169		**340**		**191**		**440**		**357**		**64**		**177**		**171**	
In-house clinic visit, n / %		47	27.8%	98	28.8%	68	35.6%	160	36.4%	117	32.8%	16	25.0%	31	17.5%	26	15.2%
Outside clinic visit, n / %		81	47.9%	114	33.5%	42	22.0%	106	24.1%	180	50.4%	30	46.9%	77	43.5%	67	39.2%
Restricted Duty (Days), n / %	**TOTAL**	**6**	**3.6%**	**28**	**8.2%**	**14**	**7.3%**	**36**	**8.1%**	**28**	**7.8%**	**2**	**3.1%**	**3**	**1.7%**	**6**	**3.5%**
	Less than 7 days	1	0.6%	7	2.1%	6	3.1%	13	3.0%	8	2.2%	0	0.0%	0	0.0%	2	1.2%
	7 - 30 days	1	0.6%	12	3.5%	5	2.6%	16	3.6%	9	2.5%	0	0.0%	2	1.1%	3	1.8%
	31 - 60 days	1	0.6%	1	0.3%	2	1.0%	1	0.2%	1	0.3%	1	1.6%	0	0.0%	0	0.0%
	61 - 90 days	0	0.0%	2	0.6%	0	0.0%	3	0.7%	1	0.3%	0	0.0%	0	0.0%	0	0.0%
	Over 90 Days	3	1.8%	6	1.8%	1	0.5%	3	0.7%	9	2.5%	1	1.6%	1	0.6%	1	0.6%
Lost Work Time (LWT) (Days), n / %	**TOTAL**	**19**	**11.2%**	**27**	**7.9%**	**9**	**4.7%**	**36**	**8.1%**	**70**	**19.6%**	**10**	**15.6%**	**21**	**11.8%**	**15**	**8.7%**
	Less than 7 days	7	4.1%	12	3.5%	6	3.1%	13	3.0%	29	8.1%	4	6.3%	9	5.1%	7	4.1%
	7 - 30 days	6	3.6%	10	2.9%	2	1.0%	16	3.6%	28	7.8%	5	7.8%	6	3.4%	3	1.8%
	31 - 60 days	3	1.8%	3	0.9%	0	0.0%	1	0.2%	6	1.7%	0	0.0%	3	1.7%	1	0.6%
	61 - 90 days	0	0.0%	0	0.0%	0	0.0%	3	0.7%	2	0.6%	0	0.0%	1	0.6%	0	0.0%
	Over 90 Days	3	1.8%	2	0.6%	1	0.5%	3	0.7%	5	1.4%	1	1.6%	2	1.1%	4	2.3%

2.2.5 Risk Factors

Although the goal of this study is to develop a continuous severity scale, initially the subjects are dichotomously defined as 'Case/Controls' based solely on the presence of pain and discomfort (Yes/No) to obtain odds ratios for multiple risk factors. Adjusted odds ratios are also calculated based on the difficulty of the job. Among the ergonomic tools used to assess job risk, the researchers used 'Expert Opinion' and rated the job from 1 to 5 for all body regions and for the individual. An expert opinion of 1 was labelled as *"Negligible/Little to no Concern"* and 5 was labelled as *"High Risk/High Concern".* These expert ratings will be used to control for the difficulty of jobs to obtain the true effect of each risk factor. Univariate binary logistic regression is used to obtain crude and adjusted odds ratios. To accomplish this, the data relating to the risk factors were taken from the structured interview form and is set and analyzed as follows:

2.2.5.1 Personal Risk-Factors:

1) **Gender** – The subjects are classified as males and females; males are considered as reference. Note: these data were collected in 1998 when gender and sex were used interchangeably. Throughout this dissertation, gender refers to biological sex as "male" or "female" and not to a subject's gender identity.
2) **Age** – Age is calculated from each subject's date of birth and was classified in the following categories: *20 – 30, 31 – 40, 41 – 50, 51 – 60, and > 60*. The age group of *20 – 30* is considered as reference.
3) **BMI** – Body Mass Index (BMI) is calculated from each subject's weight (lbs) and height (in). Using the equation, [weight (lb) / [height (in)]^2 x 703]

(Centers for Disease Control and Prevention (CDC), n.d.). Subjects are classified as *Normal, Overweight and Obese* (Centers for Disease Control and Prevention (CDC), n.d.). *Normal BMI* is considered as reference.

4) **Experience** – This data is obtained from the question, *"Time on current job (years, months, weeks)?"* and was classified into *< 3 years, 3 – 5 years, 6 – 10 years, and > 10 years*. An experience of *< 3 years* is considered as reference.
5) **Smoking History** – This data is obtained from the question, *"Are you a Current Smoker, Ex-Smoker or Never Smoked".* The *Never Smoked* category is considered as reference.
6) **Health Problems** – These data are obtained from the question, *"Have you ever been told by a health care provider that you have any of the following health problems?".* The health problems included *Diabetes, Thyroid Problems Rheumatoid Arthritis, Osteo Arthritis, Hypertension, Neurological Disorders* with a *"Yes and No"* checkbox next to each one of them. Odds ratios are obtained for each health problem with *"No"* as reference.
7) **Recreational/Outside-Work Activities** – These data are obtained from the question, *"In what kinds of out of plant activities are you or have you been involved during the last year?".* These activities included *Exercise, Sports, Hobbies, Yardwork, Outside Employment and No Activities.* Odd's ratios are obtained for each activity with *"No"* as reference.

Table 16: Individual Risk Factors and OR's (95% C.I) – Adjusted for Job Difficulty and Gender

Individual Characteristics		HEAD/NECK	SHOULDER	ELBOW	HAND/WRIST	LOW BACK	HIP	KNEE	ANKLE/FEET
Gender / Sex	Male	1	1	1	**1**	1	1	1	1
	Female	**2.2 (1.5 - 3.2)**	**1.72 (1.27 - 2.32)**	1.15 (0.8 - 1.67)	**2.84 (2.09 - 3.86)**	1.35 (0.99 - 1.83)	1.71 (0.97 - 3)	1.11 (0.76 - 1.62)	1.18 (0.8 - 1.73)
Age	20 - 30	1	1	1	1	1	1	1	1
	31 - 40	**2.8 (1.6 - 4.9)**	1 (0.66 - 1.5)	**1.75 (1.06 - 2.89)**	0.85 (0.57 - 1.27)	0.86 (0.58 - 1.29)	1.87 (0.85 - 4.11)	**1.73 (1.04 - 2.87)**	1.39 (0.86 - 2.26)
	41 - 50	**2.2 (1.3 - 3.8)**	1.23 (0.84 - 1.79)	**1.8 (1.11 - 2.89)**	**0.64 (0.44 - 0.93)**	0.79 (0.55 - 1.15)	1.15 (0.52 - 2.54)	1.32 (0.81 - 2.15)	0.83 (0.51 - 1.35)
	51 - 60	1.5 (0.8 - 2.8)	0.9 (0.57 - 1.4)	1.14 (0.64 - 2.04)	**0.6 (0.39 - 0.93)**	**0.55 (0.35 - 0.87)**	1.43 (0.6 - 3.43)	1.08 (0.6 - 1.91)	0.81 (0.46 - 1.42)
	> 60	**2.6 (1 - 6.4)**	0.8 (0.37 - 1.72)	1.37 (0.55 - 3.41)	**0.42 (0.19 - 0.91)**	0.57 (0.26 - 1.21)	0.57 (0.07 - 4.61)	0.87 (0.31 - 2.4)	0.39 (0.11 - 1.35)
BMI	Normal	1	1	1	1	1	1	1	1
	Overweight	0.99 (0.7 - 1.5)	0.8 (0.57 - 1.12)	1.4 (0.91 - 2.14)	0.88 (0.63 - 1.23)	0.98 (0.7 - 1.36)	1.71 (0.86 - 3.39)	1.52 (0.98 - 2.36)	1.24 (0.79 - 1.94)
	Obese	**0.6 (0.35 - 0.95)**	1 (0.69 - 1.44)	**1.9 (1.22 - 2.96)**	1.09 (0.76 - 1.56)	0.95 (0.66 - 1.37)	1.29 (0.59 - 2.81)	1.58 (0.99 - 2.53)	**1.8 (1.13 - 2.85)**
Smoking	Never Smoked	1	1	1	1	1	1	1	1
	Ex-Smoker	1.2 (0.7 - 1.9)	1.04 (0.72 - 1.5)	1 (0.64 - 1.55)	1.19 (0.84 - 1.7)	0.86 (0.59 - 1.24)	0.92 90.41 - 2.04)	0.94 (0.6 - 1.48)	1.13 (0.72 - 1.77)
	Current Smoker	1.5 (0.9 - 2.2)	1.16 (0.85 - 1.59)	1.19 (0.86 - 1.74)	1.14 (0.84 - 1.56)	**1.4 (1.03 - 1.91)**	1.62 (0.86 - 2.98)	1 (0.7 - 1.53)	1.02 (0.68 - 1.51)
Experience	< 3 years	1	1	1	1	1	1	1	1
	3 - 5 years	1.48 (0.99 - 2.22)	**0.7 (0.5 - 0.98)**	0.9 (0.6 - 1.35)	1.46 (0.83 - 2.56)	0.86 (0.61 - 1.19)	**1.91 (1.04 - 3.48)**	0.92 (0.61 - 1.4)	1.03 (0.68 - 1.56)
	6 - 10 years	0.74 (0.36 - 1.5)	0.62 (0.37 - 1.04)	1.21 (0.69 - 2.12)	1.31 (0.71 - 2.39)	**0.51 (0.3 - 0.87)**	0.93 (3.18 - 2.77)	0.76 (0.4 - 1.44)	0.72 (0.37 - 1.39)
	> 10 years	1 (0.47 - 2.13)	**0.53 (0.29 - 0.98)**	0.81 (0.39 - 1.65)	1 (0.53 - 2.16)	0.66 (0.37 - 1.17)	0.93 (0.27 - 3.18)	0.61 (0.28 - 1.33)	0.56 (0.25 - 1.28)
Health Problems Yes (1) No (0)	Diabetes	0.55 (0.19 - 1.61)	0.66 (0.31 - 1.41)	1 (0.42 - 2.34)	0.94 (0.46 - 1.92)	0.65 (0.3 - 1.38)	0.35 (0.04 - 2.65)	1.33 (0.59 - 2.98)	0.59 (0.2 - 1.71)
	Thyroid Problems	1.1 (0.42 - 2.86)	1.4 (0.63 - 3.1)	0.93 (0.34 - 2.54)	1.08 (0.48 - 2.43)	1.07 (0.47 - 2.4)	1.11 (0.25 - 4.9)	0.55 (0.16 - 1.89)	0.81 (0.27 - 2.42)
	Rheumatoid Arthritis	**2.27 (1.19 - 4.35)**	1.03 (0.56 - 1.88)	0.8 (0.36 - 1.74)	**2.06 (1.12 - 3.77)**	**2.71 (1.5 - 4.87)**	0.97 (0.29 - 3.87)	1.74 (0.9 - 3.36)	0.94 (0.43 - 2.06)
	Osteo Arthritis	**1.95 (1.07 - 3.56)**	1.34 (0.78 - 2.32)	1.6 (0.87 - 2.92)	1.6 (0.924 - 2.78)	**2.08 (1.22 - 3.55)**	**2.42 (1.06 - 5.48)**	**2.81 (1.59 - 4.94)**	**2.02 (1.19 - 3.67)**
	Hypertension	0.75 (0.44 - 1.26)	1.05 (0.71 - 1.53)	**1.87 (1.24 - 2.83)**	1.29 (0.88 - 1087)	1.35 (0.93 - 1.96)	1.25 (0.62 - 2.5)	1.14 (0.72 - 1.81)	1.48 (0.95 - 2.32)
	Neurological Disorders	**4.53 (1.18 - 17.36)**	**4.28 (1.05 - 17.43)**	1.15 (0.23 - 5.61)	1.11 (0.29 - 4.27)	2.36 (0.61 - 9.1)	**10.65 (2.49 - 45.46)**	0.61 (0.07 - 4.94)	0.61 (0.07 - 4.97)
Outside Activities Yes (1) No (0)	Exercise	0.99 (0.62 - 1.57)	0.74 (0.51 - 1.09)	0.88 (0.56 - 1.39)	1.24 (0.86 - 1.79)	1.35 (0.94 - 1.94)	1.51 (0.76 - 2.89)	1.48 (0.96 - 1.56)	1.28 (0.82 - 2.01)
	Sports	**1.52 (1.03 - 2.24)**	1.1 (0.82 - 1.49)	1.33 (0.93 - 1.9)	1.09 (0.81 - 1.46)	**1.37 (1.02 - 1.84)**	1.03 (0.56 - 1.86)	1.3 (0.9 - 1.88)	1.27 (0.87 - 1.84)
	Hobbies	**1.86 (1.25 - 2.77)**	1.12 (0.8 - 1.57)	1.2 (0.81 - 1.78)	1.1 (0.79 - 1.54)	1.12 (0.8 - 1.57)	1.51 (0.82 - 2.8)	1.22 (0.81 - 1.85)	1.06 (0.78 - 1.61)
	Yardwork	1.79 (0.94 - 3.39)	1.55 (0.9 - 2.65)	1.43 (0.77 - 2.65)	1.06 (0.61 - 1.84)	0.86 (0.49 - 1.52)	1.7 (0.64 - 4.5)	1.53 (0.81 - 2.87)	0.98 (0.48 - 2)
	Outside Employment	1.21 (0.62 - 2.34)	**1.67 (1 - 2.78)**	0.63 (0.3 - 1.31)	1.1 (0.65 - 1.85)	1.33 (0.8 - 2.23)	0.71 (0.21 - 0.24)	1.04 (0.54 - 2.01)	1.22 (0.53 - 2.31)
	No Activities	**0.45 (0.29 - 0.72)**	0.95 (0.69 - 1.3)	0.82 (0.56 - 1.22)	0.97 (0.71 - 1.33)	**0.64 (0.46 - 0.89)**	**0.42 (0.2 - 0.89)**	0.73 (0.48 - 1.11)	0.75 (0.49 - 1.14)

2.2.5.2 Psychophysical Risk-Factors

Rating of Perceived Exertion (RPE) is used as a measure of psychophysical risk factor. A 100-mm VAS was used to capture RPE across the Head/Neck, Shoulder, Elbow/Hand/Wrist (Upper Extremity), Low back, and Hip/Knee/Ankle/Feet (Lower Extremity). The subjects were asked to draw a vertical line that intersects the horizontal VAS scale ranging from "Low" to "High". Since this scale was 100-mm in length, it had a numerical range of 0 – 100. The researchers went back and calculated the numerical value of each subject's intensity rating by a numbered ruler, rounding to the nearest digit. The Borg's Perceived Exertion and Pain Scale (G Borg, 1970; Gunnar Borg, 1986) is a widely used tool to assess physical exertion in subjects (Li et al., 2013), especially in studies conducted in an automotive and vehicle manufacturing environment (L. Punnett et al., 2004b; Laura Punnett, 1998). In this study, the 0 – 100 visual-analog sale will be equated to the Borgs' Category Ratio (CR-10) (Gunnar Borg, 1986, 1998) and converted to a 0 – 10 scale by dividing the value by a factor of 10, for example, a score of *65* on the VAS will be calculated as a *6.5* on the Borg CR-10 scale. Literature suggests that there is significant correlation between the visual-analog scale and the Borg CR-10 scale for psychophysical estimation of intensities (Boshuizen et al., 2013; Capodaglio, 2001; Neely et al., 1992; Scott & Huskisson, 1976; Syrjala & Chapman, 1984). Further, this score is categorized as *"Low"* (Scores of 1 and 2), *"Moderate"* (Scores 3, 4, 5, 6), and *"High"* (Scores of 7, 8, 9, 10) (Buchholz et al., 2008).

Conversion is carried out to enable univariate analysis, "*Low*" category is used as reference.

Table 17: Psychophysical Risk Factor (RPE) and OR's (95% C.I) – Adjusted for Job Difficulty and gender

Psychophysical Risk Factor		HEAD/NECK	SHOULDER	ELBOW	HAND/WRIST	LOW BACK	HIP	KNEE	ANKLE/FEET
Rating of Perceived Physical Exertion (RPE)	Low	1	1	1	1	1	1	1	1
	Moderate	**1.78 (1.01 - 3.12)**	1.59 (0.86 - 2.94)	1.26 (0.41 - 3.83)	1.07 (0.49 - 2.33)	**2.28 (1.28 - 4.07)**	0.93 (0.3 - 2.82)	1.31 (0.66 - 2.6)	1.51 (0.73 - 3.13)
	High	**3.81 (2.1 - 6.92)**	**3.72 (2.03 - 6.82)**	2.15 (0.74 - 6.27)	1.69 (0.79 - 3.58)	**5.76 (3.23 - 10.29)**	2.26 (0.84 - 6.08)	**2.55 (1.34 - 4.85)**	**3.84 (1.95 - 7.57)**

Table 18: Primary Job-related Characteristics and OR's (95% C.I) - Adjusted for Gender

Job Characteristics		HEAD/NECK	SHOULDER	ELBOW	HAND/WRIST	LOW BACK	HIP	KNEE	ANKLE/FEET
Hours worked per week	< 40 hrs. (8 hr. day)	1	1	1	1	1	-NA- Insufficient cases/sample size	1	1
	40-50 (10 hr. day)	1.07 (0.13 - 8.76)	1.61 (0.33 - 7.91)	0.84 (0.17 - 4.1)	1.25 (0.3 - 5.09)	0.98 (0.24 - 3.99)		0.33 (0.82 - 1.39)	0.36 (0.08 - 1.49)
	50-60 (12 hr. day)	1.6 (0.19 - 13.0)	1.69 (0.34 - 8.27)	0.8 (0.16 - 3.9)	1.14 (0.28 - 4.65)	1.16 (0.28 - 4.7)		0.42 (0.1 - 1.75)	0.38 (0.09 - 1.58)
	Over 60 hrs.	0.92 (0.1 -8.41)	0.73 (0.13 - 3.93)	0.63 (0.11 - 3.4)	1.32 (0.3 - 5.7)	0.58 (0.13 - 2.6)		0.45 (0.1 - 2.05)	0.42 (0.09 - 1.9)
Shift worked	Day Shift	1	1	1	1	1	1	1	1
	Swing Shift	**0.65 (0.46 - 0.93)**	**0.68 (0.52 - 0.89)**	**0.69 (0.49 - 0.96)**	0.88 (0.68 - 1.14)	0.94 (0.72 - 1.22)	0.95 (0.57 - 1.59)	0.83 (0.59 - 1.16)	0.88 (0.63 - 1.24)

2.2.5.3 Psychosocial Risk-Factors

Two different sets of psychosocial questions were asked to the subjects in the structured interview form:

1. **Employee Perceptions on Work and Health** – This question set consisted of 14 questions using a 4-point Likert scale with a response ranging from *Strongly Disagree* to *Strongly Agree.* These questions are a subset of the Kraseks's Job Content Questionnaire (JCQ) (Robert Karasek et al., 1998, 2007). The questions will be classified into 'Skill Discretion', 'Job Control', 'Psychological Job Demands' and 'Social Support' (Bernardes Santos et al., 2016; Choi et al., 2012; Robert Karasek et al., 1998; Kawakami et al., 1995). The responses are categorized dichotomously into 'Agree' *(Strongly Agree and Agree)* and 'Disagree' *(Disagree and Strongly Disagree*). Crude and adjusted (adjusted for job difficulty) odds ratios are calculated for each question using logistic regression analysis. 'Agree' response to the questions is considered as reference.
2. **Job Satisfaction** – This question set consisted of 3 questions using a 4-point scale (1. *No*, 2. *Little*, 3. *Somewhat*, and 4. *Very*). The questions asked were; a) *"All in all, how satisfied are you in your job?",* b) *"How strongly would you recommend your job to someone else?",* and c) *"If you were looking for a new job, how likely is it that you would take this job again?".* The responses are categorized in to 'Little to None' (*No and Little*) and 'Very' (*Somewhat Likely and Very Likely).* Crude and adjusted

(adjusted for job difficulty) odd's ratios are calculated for each question using logistic regression analysis. 'Very' response to the questions is considered as reference.

Table 19: Psychosocial & Psychological Risk Factors and Crude OR's (At least 95% C.I)

Psychosocial variable (Disagree = 0, Agree = 1)	**N**	**Any**	**Head/Neck**	**Shoulder**	**Upper Extremity**	**Low Back**	**Lower Extremity**
Require learning new things	995	**0.61 (0.46 - 0.84)**	0.86 (0.62 - 1.21)	0.97 (0.75 - 1.27)	**0.74 (0.58 - 0.97)**	**0.63 (0.49 - 0.82)**	**0.745 (0.57 - 0.98)**
Involves repetitive work	996	**1.582 (0.87 - 2.87)**	1.61 (0.67 - 3.83)	1.6 (0.84 - 3.02)	1.49 (0.86 - 2.59)	1.749 (0.92 - 3.31)	1.78 (0.91 - 3.51)
Requires to be creative	996	**0.59 (0.44 - 0.80)**	0.8 (0.55 - 1.15)	0.96 (0.72 - 1.28)	**0.71 (0.55 - 0.94)**	**0.62 (0.47 - 0.83)**	0.82 (0.62 - 1.1)
Requires high skill	995	**0.73 (0.55 - 0.99)**	**0.56 (0.39 - 0.82)**	0.86 (0.66 - 1.14)	**0.72 (0.56 - 0.95)**	0.77 (0.59 - 1.01)	0.85 (0.64 - 1.12)
Little freedom	995	**1.95 (1.43 - 2.66)**	**1.41 (1.01 - 1.97)**	**1.43 (1.1 - 1.87)**	**1.46 (1.13 - 1.91)**	**1.59 (1.23 - 2.07)**	**1.76 (1.34 - 2.3)**
Requires learning variety of things	996	0.95 (0.71 - 1.28)	0.97 (0.69 - 1.36)	1.1 (0.84 - 1.43)	0.87 (0.68 - 1.13)	0.88 (0.68 - 1.14)	0.94 (0.72 - 1.24)
I have say	994	**0.44 (0.33 - 0.61)**	**0.47 (0.33 - 0.67)**	0.77 (0.59 - 1)	**0.58 (0.45 - 0.76)**	0.62 (0.48 - 0.81)	**0.58 (0.45 - 0.77)**
Requires working fast	996	**2.19 (1.6 - 3)**	1.47 (0.97 - 2.22)	**1.62 (1.17 - 2.22)**	**1.77 (1.33 - 2.36)**	**1.6 (1.17 - 2.17)**	**1.48 (1.07 - 2.04)**
Requires working hard	996	**2.53 (1.87 - 3.43)**	**1.65 (1.13 - 2.42)**	**1.71 (1.28 - 2.29)**	**2.04 (1.56 - 2.68)**	**1.94 (1.45 - 2.59)**	1.28 (0.96 - 1.71)
No excessive work	995	**0.38 (0.28 - 0.54)**	**0.7 (0.49 - 0.98)**	**0.53 (0.41 - 0.7)**	**0.41 (0.31 - 0.54)**	**0.62 (0.48 - 0.81)**	0.55 (0.42 - 0.73)
I have enough time	990	**0.23 (0.12 - 0.46)**	**0.5 (0.32 - 0.77)**	**0.6 (0.41 - 0.87)**	**0.4 (0.25 - 0.61)**	0.69 (0.48 - 1.01)	**0.55 (0.38 - 0.79)**
Job is Hectic	996	**1.80 (1.34 - 2.43)**	**2.25 (1.57 - 3.2)**	**1.62 (1.24 - 2.11)**	**1.4 (1.08 - 1.8)**	**1.76 (1.35 - 2.29)**	**1.6 (1.22 - 2.1)**
Can take a break	994	**0.51 (0.37 - 0.7)**	**0.54 (0.36 - 0.83)**	**0.64 (0.47 - 0.87)**	**0.5 (0.38 - 0.67)**	**0.68 (0.51 - 0.92)**	**0.61 (0.45 - 0.85)**
Supervisor support available	986	**0.30 (0.19 - 0.49)**	**0.62 (0.42 - 0.9)**	**0.67 (0.49 - 0.91)**	**0.48 (0.34 - 0.67)**	0.75 (0.55 - 1.02)	**0.47 (0.35 - 0.65)**
Psychological Risk Factors (*Job Satisfaction*) (Very = 0, Not at all = 1)							
Jsat-Satisfied with job	993	**5.73 (2.87- 11.42)**	**1.58 (1.03 - 2.43)**	**1.5 (1.05 - 2.13)**	**3.6 (2.3 - 5.65)**	**2.23 (1.57 - 3.16)**	**1.67 (1.17 - 2.38)**
Jsat-Will recommend this job	995	**4.0 (2.69 - 5.89)**	**2.25 (1.6 - 3.16)**	**2.12 (1.61 - 2.79)**	**3.17 (2.3 - 4.29)**	**1.96 (1.5 - 2.57)**	**1.83 (1.39 - 2.42)**
Jsat-Will take this job again	993	**4.32 (2.69 - 6.94)**	**1.7 (1.18 - 2.44)**	**2.14 (1.59 - 2.87)**	**3.35 (2.37 - 4.75)**	**1.85 (1.38 - 2.48)**	**1.75 (1.3 - 2.37)**

The original Karasek's Job Content Questionnaire (JCQ)(R. Karasek et al., 1998) consists of 49 questions while this study contains a subset consisting of 17 questions [*Appendix 2*] which were asked by the OHN's to the subjects at the end of the structured interview. Out of the 17 questions, 14 related to employees' perceptions of work and health (psychosocial questions) where subjects were provided with a 4-point Likert scale, with response ranging from 'Strongly Disagree' to 'Strongly Agree'. A 3 question Job Satisfaction (psychological questions) questionnaire was also asked, responses for these questions ranged from 'Not at all' to 'Very'. A complete list of the question set along with the abbreviations used in this study can be found in [*Appendix 6*].

The larger purpose of this study is to identify key psychosocial and psychological risk-factor categories that can be analyzed when building a holistic predictive model involving multiple risk factors. Including individual questions in a model makes little sense which is why the questions are combined to form relevant categories. Questions were grouped into categories (*Table 21*) such as Skill Discretion, Decision Authority, Job Control, Job Demands and Supervisor Support (R. Karasek et al., 1998)

Some of the questions are reverse scored if they fit their categories according to literature but were negatively correlated to the other items that made up that category. For example, the category Job Control deals with the amount of control an employee has over their respective job and is made up of the items; *new things, creative, high skill, repetition, say, freedom and variety*, where we assume that these questions have a positive effect as their response scale increases (from left to right). Questions such as "My job requires a **lot** of repetitive work", and "I have **very little** freedom to decide how I work" have the same direction of scale, i.e "Strongly Disagree" to "Strongly Agree"

however, in the case of these questions as the response scale increases (from left to right), they have a negative effect on the employees' overall response. This is further confirmed when these two questions were found to be negatively correlated to with all the other items that make up the category Job Control. This why the response scales are reverse scored to effectively transform the question into "My job requires **less** repetitive work", and "I have **a lot of** freedom to decide how I work". An overall score for the categories (category score) was developed by summing the scores (1 – 4 Likert Score) of the individual questions that make up the category. Additional categories such as Decision Latitude and Job Strain are also calculated using the previously mentioned category scores. Decision Latitude is calculated as the sum of scores of Skill Discretion and Decision Authority. Job Strain is calculated by dividing Job Demands with Job Control (Ota et al., 2015).

It was a priori decided that crude odd's ratios for each individual question will be presented *Table 20* irrespective of the results obtained from the reliability analysis. Reliability of the categories was tested using Cronbach's α, where an α level of **0.7** will be accepted and termed reliable (Bonett & Wright, 2015; Chua, 2006; George & Mallery, 2003; Pallant, 2001; Pallant & Manual, 2001)

Table 20: Psychosocial Risk Factors: Categories and reliability analyses

Category	Question Items	Cronbachs's α
Skill Discretion	*Requires learning new things*	**0.714**
	Involves repetitive work (rev)	
	Requires to be creative	
	Requires high skill	
	Requires learning variety of things	
Decision Authority	*I have say*	0.51
	Little freedom (rev)	
Job Control	*Requires learning new things*	**0.726**
	Involves repetitive work (rev)	
	Requires to be creative	
	Requires high skill	
	Little freedom (rev)	
	Requires learning variety of things	
	I have say	
Job Demand	*Requires working fast*	**0.707**
	Requires working hard	
	No excessive work (rev)	
	I have enough time (rev)	
	Job is Hectic	
Job Satisfaction	*Jsat-Satisfied with job*	**0.824**
	Jsat-Will recommend this job	
	Jsat-Will take this job again	
Supervisor Support	*Supervisor support available*	-

To test associations and obtain OR's, binary logistic regression analyses is used because of which, category scores were classified as 'High' or 'Low' by running descriptive statistics and dividing the total score obtained into two equal parts based on their frequencies. For example, the category Job Satisfaction is made of three questions; a) *"Satisfied with job"*, b) *"Will recommend this job*", and c) *"Will take this job again"*. Each of these questions have a 4-point scale with a direction of 'Not at all' to 'Very', which makes the range of the category score 3 – 12. Running a descriptive analysis on this score provided us with a cut point of 9 based on their frequencies. Scores from 3 through 9 were classified as "Low", and score from 10 through 12 are classified as "High". OR's are presented by first adjusting for age and gender *Table 22*, and then for gender, age, and job difficulty *Table 23*.

Job difficulty is determined by ratings obtained by the expert opinion of researchers with significant ergonomics training and ergonomists. Expert opinion has been used in the ergonomic literature to conduct job analyses, assess occupational exposures (Morgan & Mansfield, 2014), evaluate office ergonomics (Ketola et al., 2004), and in developing ergonomic risk-assessment tools (Hignett & Ergonomist, 2000). In addition, there is evidence of using expert ratings for physical exposures to study psychosocial risk factors as predictors of injury and musculoskeletal disorder risk in a similar manufacturing cohort (Cantley et al., 2016). In this study, expert opinion is used to control for the physical exposure from performing the jobs. In the original study, the ergonomists rated the difficulty of each job on a scale of 1 – 5 with 1 being "Easy (Little to no concern)" to 5 being "Hard (High Concern)" for the head/neck, shoulder, upper extremity, low back, lower extremity, and the entire body as whole.

Table 21: Psychosocial and Psychological Categories and OR's (At least 95% C.I) – Adjusted for Sex, and Age

Psychosocial & Psychological Categories	Any	Head/Neck	Shoulder	Upper Extremity	Low Back	Lower Extremity
Job Demand						
Low	1	1	1	1	1	1
High	**3.96 (2.62 - 5.98)**	**2.24 (1.57 - 3.2)**	**2.27 (1.7 - 3.01)**	**2.15 (1.62 - 2.85)**	**1.99 (1.5 - 2.63)**	**1.81 (1.35 - 2.41)**
Job Control						
High	1	1	1	1	1	1
Low	**1.77 (1.29 - 2.43)**	**1.63 (1.12 - 2.37)**	1.22 (0.92 - 1.62)	**1.63 (1.24 - 2.13)**	**1.8 (1.36 - 2.4)**	**1.33 (1 - 1.79)**
Job Strain						
Low	1	1	1	1	1	1
High	**3.51 (2.48 - 4.98)**	**2.21 (1.52 - 3.2)**	**1.85 (1.39 - 2.45)**	**2.13 (1.62 - 2.79)**	**2.49 (1.87 - 3.3)**	**2.04 (1.52 - 2.74)**
Job Satisfaction						
High	1	1	1	1	1	1
Low	**3.41 (2.48 - 4.68)**	**2.19 (1.48 - 3.23)**	**2.18 (1.62 - 2.91)**	**2.22 (1.7 - 2.91)**	**2.11 (1.58 - 2.81)**	**1.99 (1.78 - 2.69)**
Supervisor Support						
High	1	1	1	1	1	1
Low	**2.98 (1.85 – 4.8)**	**1.58 (1.07 – 2.34)**	**1.43 (1.04 – 1.97)**	**1.69 (1.23 - 2.32)**	1.26 (0.92 – 1.73)	**2.1 (1.52 – 2.88)**
Decision Latitude						
High	1	1	1	1	1	1
Low	**1.77 (1.29 - 2.43)**	**1.63 (1.12 - 2.37)**	1.22 (0.92 - 1.62)	**1.63 (1.24 - 2.13)**	**1.8 (1.36 - 2.4)**	**1.33 (1 - 1.79)**

Table 22: Psychosocial and Psychological Categories and OR's (At least 95% C.I) – Adjusted for Sex, Age, and Job Difficulty

Psychosocial & Psychological Categories	Any	Head/Neck	Shoulder	Upper Extremity	Low Back	Lower Extremity
Job Demand						
Low	1	1	1	1	1	1
High	**3.4 (2.2 - 5.22)**	**2.15 (1.48 - 3.12)**	**2.2 (1.64 - 2.96)**	**1.98 (1.47 - 2.66)**	**2.52 (1.82 - 3.49)**	**1.6 (1.18 - 2.16)**
Job Control						
High	1	1	1	1	1	1
Low	**1.75 (1.25 - 2.47)**	**1.6 (1.09 - 2.36)**	1.27 (0.95 - 1.71)	**1.56 (1.17 - 2.07)**	**1.75 (1.3 - 2.35)**	**1.39 (1.02 - 1.88)**
Job Strain						
Low	1	1	1	1	1	1
High	**3.35 (2.3 - 4.87)**	**2.14 (1.46 - 3.15)**	**1.79 (1.33 - 2.41)**	**2.05 (1.54 - 2.73)**	**2.42 (1.8 - 3.27)**	**2.03 (1.49 - 2.76)**
Job Satisfaction						
High	1	1	1	1	1	1
Low	**3.33 (2.37 - 4.69)**	**2.21(1.47 - 3.35)**	**2.11 (1.55 - 2.86)**	**2.18 (1.64 - 2.9)**	**2.12 (1.57 - 2.86)**	**1.87 (1.37 - 2.55)**
Supervisor Support						
High	1	1	1	1	1	1
Low	**3.61 (2.08 – 6.26)**	**1.51 (1 – 2.28)**	**1.42 (1.01 – 1.98)**	**1.79 (1.27 - 2.52)**	1.26 (0.91 – 1.76)	**2.22 (1.58 – 3.1)**
Decision Latitude						
High	1	1	1	1	1	1
Low	**1.75 (1.25 - 2.47)**	**1.6 (1.09 - 2.36)**	1.24 (0.92 - 1.66)	**1.56 (1.17 - 2.07)**	**1.78 (1.32 - 2.4)**	**1.41 (1.03 - 1.91)**

2.3 Results

2.3.1 Prevalence & Characteristics

Prevalence and characteristics of musculoskeletal pain and discomfort across all anatomical sites is presented in *Table 15*.

Highest prevalence of musculoskeletal pain & discomfort was observed in Hand/Wrist at 43% (n=440), followed by Low Back at 35% (n=357), Shoulder at 33% (n=40), Elbow at 19% (n=191), Knee at 17% (n=177), Ankle/Feet at 17% (n=171), Head/Neck at 17% (n=169), and lastly in Hips at 6% (n=64).

Subjects self-reported intensity of pain on the day of data collection on a 0-100 VAS. Highest mean intensity of pain was observed in the following anatomical sites in a descending order: Ankle/Feet (30.2 ± 27.2), Head/Neck (27.72 ± 22.6), Hand/Wrist (27.5 ± 24.2), Low Back (25.7 ± 25), Elbow (25.7 ± 23.7) Shoulder (23.7 ± 23.6), Knee (23.2 ± 24.4), and Hip (20.9 ± 22.5).

Subjects also self-reported intensity of worst pain in the last year from the day of data collection on a 0-100 VAS. Highest mean intensity of worst pain in the last year was observed in the following anatomical sites in a descending order: Low Back (76 ± 20.3), Ankle/Feet (73.6 ± 23.2), Head/Neck (73.6 ± 18.6), Hip (72.9 ± 22.9), Hand/Wrist (70.6 ± 20.5), Shoulder (69.8 ± 20.9), Elbow (67.7 ± 20.6), and Knee (67.3 ± 22.7).

2.3.2 Consequences

Consequences of musculoskeletal pain and discomfort across all anatomical sites is presented in *Table 16*.

Out of the subjects indicating pain in Head/Neck – 76% (n=128) had clinic visits, 3.6% (n=6) were placed on a restricted duty, and 11.2% (n=19) had lost work time days.

Out of the subjects indicating pain in Shoulder – 62% (n=212) had clinic visits, 8.2% (n=28) were placed on a restricted duty, and 7.9% (n=27) had lost work time days.

Out of the subjects indicating pain in Elbow – 58% (n=110) had clinic visits, 7.3% (n=14) were placed on a restricted duty, and 4.7% (n=9) had lost work time days.

Out of the subjects indicating pain in Hand/Wrist – 60% (n=266) had clinic visits, 8.1% (n=36) were placed on a restricted duty, and 8.1% (n=36) had lost work time days.

Out of the subjects indicating pain in Low Back – 83% (n=297) had clinic visits, 7.8% (n=28) were placed on a restricted duty, and 19.6% (n=70) had lost work time days.

Out of the subjects indicating pain in Hips – 72% (n=46) had clinic visits, 3.1 (n=2) were placed on a restricted duty, and 15.6% (n=10) had lost work time days.

Out of the subjects indicating pain in Knees – 61% (n=108) had clinic visits, 1.7% (n=3) were placed on a restricted duty, and 11.8% (n=21) had lost work time days.

Out of the subjects indicating pain in Ankle/Feet – 54% (n=93) had clinic visits, 3.5% (n=6) were placed on a restricted duty, and 8.7% (n=15) had lost work time days.

2.3.3 Risk Factors

2.3.3.1 Personal Risk Factors

Personal risk factors associated with of musculoskeletal pain and discomfort across all anatomical sites is presented in *Table 17.*

Sex, age, BMI, pre-diagnosed medical conditions, and engaging in outside job activities were significantly associated with Head/Neck pain and discomfort.

Sex, years of experience, pre-diagnosed medical conditions, and engaging in outside job activities were significantly associated with Shoulder pain and discomfort.

Age, BMI, and pre-diagnosed medical conditions were significantly associated with Elbow pain and discomfort.

Sex, age, and pre-diagnosed medical conditions were significantly associated with Hand/Wrist pain and discomfort.

Age, smoking status, years of experience, pre-diagnosed medical conditions, and engaging in outside job activities were significantly associated with Low Back pain and discomfort.

Years of experience, pre-diagnosed medical conditions, and engaging in outside job activities were significantly associated with Hip pain and discomfort.

Age, and pre-diagnosed medical conditions were significantly associated with Knee pain and discomfort.

BMI, and pre-diagnosed medical conditions were significantly associated with Ankle/Feet pain and discomfort.

2.3.3.2 Psychophysical Risk Factors

Psychophysical risk factors associated with of musculoskeletal pain and discomfort across all anatomical sites is presented in *Table 18.*

RPE was significantly associated with pain and discomfort in Head/Neck, Shoulder, Low Back, Knee, and Ankle/Feet.

2.3.3.3 Primary Job-Related Risk Factors

Primary Job-Related risk factors associated with of musculoskeletal pain and discomfort across all anatomical sites is presented in *Table 19.*

Type of shift worked (Day shift/Swing shift) was significantly associated with pain and discomfort in Head/Neck, Shoulder, and Elbow.

2.3.3.4 Psychosocial Risk Factors

Psychosocial risk factors associated with of musculoskeletal pain and discomfort across all anatomical sites is presented in *Table 22*, and *Table 23.*

High *Job Demand* was significantly associated with pain and discomfort of all anatomical sites.

Low *Job Control* was significantly associated with pain and discomfort of all anatomical sites, except for Shoulder.

High *Job Strain* was significantly associated with pain and discomfort of all anatomical sites.

Low *Job Satisfaction* was significantly associated with pain and discomfort of all anatomical sites.

Low *Supervisor Support* was significantly associated with pain and discomfort of all anatomical sites, except for Low Back.

Low *Decision Latitude* was significantly associated with pain and discomfort of all anatomical sites, except for Shoulder.

Chapter 3: Identifying Multi-Site Associations of Pain & Discomfort

3.1 Introduction

The previous study aimed to identify associations between localized pain and discomfort on a single anatomical site and multiple risk factors. However, musculoskeletal pain is often widespread and occurs on multiple anatomical sites (Coggon et al., 2013). Epidemiological research concentrating solely on localized pain fails to provide a complete picture of the progression and severity of an injury (Kamaleri et al., 2008, 2009). Moreover, it is not only common to develop pain on multiple sites in the same anatomical region but also in completely different regions at the same time (Picavet & Schouten, 2001). (Parot-Schinkel et al., 2012) states that, there is a need to conduct further research to clearly identify the determinants of multi-site pain. This study aims to investigate the prevalence of multi-site pain and discomfort, identify associations between multi-site pain and multiple risk factors simultaneously, and identify associations among the pairs of multi-site pain (Simon S. Yeung et al., 2002).

3.2 Methods

Multi-site pain is defined as presence of pain and discomfort in at least two sites. Several other categories are also created that combine individual anatomical site into anatomical regions such as, a) *Head/Neck and Shoulder*, b) *Elbow and Hand/Wrist*, c) *Upper Extremity (Shoulder, Elbow and Hand/Wrist),* d) *Lower Extremity (Hip, Knee and Ankle/Feet)* as well as general categories such as e) *At least 2 sites*, f) *At least 3 sites*, g) *At least 5 sites* and h) *All sites* (Neupane et al., 2013, 2016). Combining anatomical sites can also be beneficial when referred pain is present such as in the head/neck and shoulder

where it can be difficult for subject's to clearly distinguish pain and injury locations. For example, the muscles of the neck transition into and overlap with the shoulder muscles; an injury in one or the other can result in pain "referred" to the nearby region (e.g., shoulder injury that results in neck discomfort or vice versa). Subjects are classified as 'Cases' if they indicate presence of pain and discomfort.

The purpose of this experiment is to test the hypotheses that; **There exists significant associations among the pairs of multi-site pain**. The original study was cross-sectional in nature with some retrospective aspects. In the subject interview form the subjects were asked to indicate their intensity of a) Worst pain in the last year, and b) Intensity of pain today on a 0-100 VAS. This retrospective aspect of the study is leveraged to form a current "Prospect-*ish*" study – meaning 'worst pain in the last year' is used to predict 'pain today'.

Since the subjects scored their intensity of pain on a 0-100 VAS, two analyses are conducted with different threshold values of intensity of symptom – a) Intensity of worst pain in the last year greater than 15 on a scale of 0-100 VAS, and b) intensity of worst pain in the last year greater than 50 on a 0-100 VAS. This will enable correcting for individuals that indicated a minimal symptom such as a pain rating of 2/100.

Prevalence of pain at a single anatomical site will be determined if the employee marked a score greater than 15 for intensity of 'pain today' on a 0-100 VAS. Logical operators (AND, OR) will be used to determine prevalence of multisite pain depending on the categories listed in *Table 24.* For example, an employee will be considered a 'Case' for Lower Extremity (LE), if they answered 'Yes' to *Hip Pain* **OR** *Knee Pain* **OR**

Ankle/Feet Pain. Overall prevalence for each category is calculated and further broken down by gender. Prevalence is listed as a percentage.

Univariate binary logistic regression analysis is used to identify associations among the pairs of multi-site pain and discomfort. In this experiment, all of the variables are 'Cases', i.e. present symptoms, but in this study 'worst pain in the last year (WP)' will function as an independent variable and 'pain today (PT)' will function as an dependent variable. For example, if we want to test the hypothesis, "How likely is it that an individual that experienced elbow pain in the last year, will also experience pain in the wrist today". Crude and adjusted (adjusted for sex and age) odd's ratios is reported in *Table 25 (WP>15, PT>15)* and *Table 26 (WP>50, PT>15).* Significance is determined at $p < 0.05$ level.

Table 23: Prevalence of Multisite Pain

Anatomical Site	Overall Prevalence (%)		Prevalence Distributed by Gender (%)			
			Males		Females	
			735		274	
	n	%	n	%	n	%
Head/ Neck & Shoulder	400	39.4%	263	35.8%	137	50.0%
Elbow & Hand/Wrist	527	51.9%	345	46.9%	179	65.3%
(UE) Shoulder, Elbow & Hand/Wrist	640	63.0%	432	58.8%	205	74.8%
(LE) Hip, Knee & Ankle/Feet	306	30.1%	215	29.3%	90	32.8%
At least 2 sites	526	52.1%	343	46.7%	183	66.8%
At least 3 sites	313	30.8%	206	28.0%	106	38.7%
At least 4 sites	147	14.5%	92	12.5%	55	20.1%
At least 5 sites	79	7.8%	47	6.4%	32	11.7%
At least 6 sites	42	4.1%	22	3.0%	50	18.2%
At least 7 sites	12	1.2%	7	1.0%	5	1.8%
All 8 sites	4	0.4%	0	0.0%	4	1.5%

Table 24: Multisite association of pain across all anatomical sites (WP>15, PT>15) with OR's (95% C.I) - Adjusted for sex and age

		PT > 15 (Pain Today)												
		HN	**Sh**	**El**	**HW**	**Lb**	**Hip**	**Kn**	**AF**	**HN & Sh**	**El & HW**	**Any UE**	**Any LE**	**ANY**
WP>15 (Past Year)	**n (%)**	116 (11.4)	211 (20.8)	108 (10.6)	268 (26.4)	205 (20.2)	31 (3.1)	92 (9.1)	109 (10.7)	265 (26.1)	327 (32.2)	423 (41.6)	196 (19.3)	564 (55.5)
HN	169 (16.6)	**1**	**2.9 (1.9 - 4.3)**	1.2 (0.7 - 2.1)	1.4 (0.9 - 2.1)	**2.1 (1.4 - 3.2)**	**3.4 (1.5 - 7.7)**	**2.2 (1.3 - 3.7)**	1.6 (0.9 - 2.7)	**12.2 (8.2 - 18)**	**1.4 (1.0 - 2.1)**	**1.8 (1.3 - 2.6)**	**2.0 (1.3 - 3.0)**	**4.9 (3.1 - 7.7)**
Sh	340 (33.5)	**3.5 (2.3 - 5.4)**	**1**	**2.1 (1.3 - 3.2)**	**1.8 (1.3 - 2.5)**	**2.1 (1.5 - 2.9)**	1.8 (0.8 - 3.9)	**2.0 (1.2 - 3.1)**	**2.3 (1.4 - 3.5)**	---	**1.9 (1.4 - 2.5)**	**6.7 (4.9 - 9.0)**	**1.9 (1.4 - 2.7)**	**5.3 (3.9 - 7.3)**
El	191 (18.8)	1.5 (0.9 - 2.5)	**2.5 (1.7 - 3.6)**	**1**	**2.0 (1.4 - 2.9)**	1.2 (0.8 - 1.8)	2.0 (0.8 - 4.6)	**2.4 (1.4 - 3.9)**	1.3 (0.8 - 2.1)	**2.1 (1.5 - 2.9)**	**7.6 (5.3 - 11)**	**6.3 (4.3 - 9.1)**	**1.6 (1.1 - 2.4)**	**5.1 (3.4 - 7.7)**
HW	440 (43.3)	**2.2 (1.4 - 3.5)**	**2.2 (1.6 - 3.1)**	**1.7 (1.1 - 2.7)**	**1**	**1.5 (1.1 - 2.2)**	1.7 (0.7 - 3.8)	**2.7 (1.6 - 4.3)**	**1.5 (1.0 - 2.4)**	**2.3 (1.7 - 3.0)**	---	**8.9 (6.6 - 12)**	**1.9 (1.4 - 2.7)**	**4.8 (3.6 - 6.4)**
Lb	357 (35.1)	**3.0 (1.9 - 4.6)**	**2.2 (1.4 - 2.7)**	1.2 (0.8 - 1.9)	**1.6 (1.2 - 2.2)**	**1**	**8.6 (3.2 -23.3)**	**2.2 (1.4 - 3.6)**	**2.2 (1.4 - 3.4)**	**2.3 (1.7 - 3.1)**	**1.6 (1.2 - 2.1)**	**1.9 (1.4 - 2.5)**	**2.7 (1.9 - 3.8)**	**5.4 (4.0 - 7.4)**
Hip	64 (6.3)	**3.6 (1.9 - 6.7)**	1.5 (0.8 - 2.8)	1.7 (0.8 - 3.5)	1.4 (0.8 - 2.5)	**2.7 (1.5 - 4.8)**	**1**	**3.3 (1.7 - 6.5)**	**3.2 (1.7 - 6.1)**	**2.2 (1.3 - 3.7)**	1.6 (0.9 - 2.7)	**1.7 (1.0 - 2.9)**	---	**4.3 (2.1 - 8.7)**
Kn	177 (17.4)	**2.4 (1.5 - 3.8)**	1.4 (0.9 - 2.1)	1.6 (0.9 - 2.6)	**2.0 (1.4 - 3.0)**	**1.6 (1.1 - 2.4)**	2.1 (0.9 - 4.9)	**1**	**3.0 (1.9 - 4.8)**	**1.6 (1.1 - 2.3)**	**1.7 (1.2 - 2.4)**	**1.7 (1.2 - 2.4)**	---	**2.7 (1.9 - 4.0)**
AF	171 (16.8)	**2.7 (1.7 - 4.2)**	**2.1 (1.4 - 3.1)**	1.2 (0.7 - 2.0)	**1.6 (1.1 - 2.4)**	**1.8 (1.2 - 2.7)**	2.0 (0.8 - 4.8)	**4.5 (2.8 - 7.2)**	**1**	**2.5 (1.7 - 3.5)**	**1.8 (1.2 - 2.5)**	**1.9 (1.4 - 2.7)**	---	**5.4 (3.5 - 8.5)**

Table 25: Multisite association of pain across all anatomical sites (WP>50, PT>15) with OR's (95% C.I) - Adjusted for sex and age

		PT > 15 (Pain Today)												
		HN	**Sh**	**El**	**HW**	**Lb**	**Hip**	**Kn**	**AF**	**HN & Sh**	**El & HW**	**Any UE**	**Any LE**	**ANY**
WP > 50 (Past Year)	**n (%)**	116 (11.4)	211 (20.8)	108 (10.6)	268 (26.4)	205 (20.2)	31 (3.1)	92 (9.1)	109 (10.7)	265 (26.1)	327 (32.2)	423 (41.6)	196 (19.3)	564 (55.5)
HN	153 (15.1)	**1**	**3.3 (2.2 - 5.0)**	1.5 (0.9 - 2.6)	**1.8 (1.2 - 2.7)**	**2.3 (1.5 - 3.5)**	**4.0 (1.8 - 9.1)**	**2.4 (1.4 - 4.1)**	**1.6 (1.0 - 2.8)**	---	**1.7 (1.2 - 2.5)**	**2.3 (1.6 - 3.3)**	**2.2 (1.5 - 3.3)**	**6.6 (3.9 - 10.9)**
Sh	285 (28.1)	**4.1 (2.7 - 6.4)**	**1**	**2.8 (1.8 - 4.4)**	**2.1 (1.5 - 2.9)**	**2.4 (1.7 - 3.4)**	1.5 (0.7 - 3.4)	**2.0 (1.3 - 3.2)**	**2.2 (1.4 - 3.4)**	---	**2.3 (1.7 - 3.1)**	---	**2.0 (1.4 - 2.8)**	**6.2 (4.4 - 8.9)**
El	164 (16.1)	1.4 (0.9 - 2.4)	**2.6 (1.8 - 3.9)**	**1**	**2.4 (1.6 - 3.5)**	1.2 (0.8 - 1.9)	1.6 (0.6 - 4.1)	**2.7 (1.6 - 4.5)**	1.3 (0.8 - 2.3)	**2.2 (1.5 - 3.1)**	---	---	**1.7 (1.2 - 2.6)**	**6.3 (3.9 - 10.1)**
HW	376 (37)	**2.5 (1.6 - 3.9)**	**2.4 (1.7 - 3.4)**	**2.3 (1.5 - 3.6)**	**1**	**1.9 (1.3 - 2.7)**	1.65 (0.75 3.64)	**3.3 (2.0 - 5.4)**	**1.5 (1.0 - 2.4)**	**2.4 (1.8 - 3.3)**	---	---	**2.4 (1.7 - 3.3)**	**6.3 (4.6 - 8.6)**
Lb	334 (32.9)	**2.9 (1.9 - 4.4)**	**2.1 (1.5 - 3.0)**	1.3 (0.8 - 2.1)	**1.7 (1.2 - 2.4)**	**1**	**7.8 (3.0 - 19.7)**	**2.5 (1.6 - 4.0)**	**2.0 (1.3 - 3.2)**	**2.4 (1.8 - 3.2)**	**1.7 (1.3 - 2.3)**	**2.1 (1.6 - 2.8)**	**2.7 (2.0 - 3.8)**	**6.1 (4.4 - 8.5)**
Hip	54 (5.3)	**3.8 (1.9 - 7.5)**	1.5 (0.8 - 3.0)	1.6 (0.7 - 3.7)	1.4 (0.7 - 2.7)	**3.2 (1.7 - 6.0)**	**1**	**3.9 (1.9 - 7.8)**	**3.9 (1.9 - 7.6)**	**2.2 (1.2 - 3.9)**	1.5 (0.8 - 2.7)	**1.8 (1.0 - 3.1)**	---	**5.3 (2.3 - 12.1)**
Kn	146 (14.4)	**2.2 (1.3 - 3.6)**	**1.5 (1.0 - 2.3)**	**2.0 (1.2 - 3.3)**	**2.1 (1.4 - 3.2)**	**1.7 (1.1 - 2.6)**	**2.83 (1.2 - 6.5)**	**1**	**2.8 (1.7 - 4.7)**	**1.6 (1.1 - 2.4)**	**1.9 (1.3 - 2.8)**	**1.9 (1.3 - 2.8)**	---	**3.6 (2.3 - 5.5)**
AF	147 (14.5)	**2.9 (1.8 - 4.7)**	**2.3 (1.5 - 3.4)**	1.6 (0.9 - 2.7)	**1.7 (1.1 - 2.6)**	**2.1 (1.4 - 3.2)**	**2.3 (1.0 - 5.5)**	**4.6 (2.8 - 7.6)**	**1**	**2.7 (1.8 - 3.9)**	**1.8 (1.3 - 2.7)**	**2.1 (1.5 - 3.1)**	---	**8.7 (4.9 - 15.1)**

3.3 Results

3.3.1 Prevalence of multisite pain

Overall prevalence of employees/subjects experiencing multisite pain is reported in *Table 24.*

529 employees, out of which 342 were males and 183 were females experienced pain in at least 2 anatomical sites at the same time.

400 employees, out of which 263 were males and 137 were females experienced pain in Head/Neck and Shoulder at the same time.

527 employees, out of which 345 were males and 179 were females experienced pain in Elbow and Hand/Wrist at the same time.

640 employees, out of which 432 were males and 205 were females indicated that they experienced pain in at least one of the upper extremity (UE) sites (Shoulder, Elbow, Hand/Wrist).

306 employees, out of which 215 were males and 90 were females indicated that they experienced pain in at least one of the lower extremity (LE) sites (Hip, Knee, Ankle/Feet).

4 employees, all females indicated that they were experiencing some level pain at all 8 sites.

3.3.2 Multisite association of pain (WP > 15, PT > 15)

Multisite association of pain adjusted for sex and age across all anatomical sites with their respective confidence intervals is reported in *Table 25*.

Head/Neck pain (WP>15) in the past year was found to be significantly associated with pain today (PT>15) in Shoulder, Low back, Hip, Knee, Head/Neck & Shoulder together, Elbow and Hand/Wrist together, at least 1 UE site, and at least 1 LE site.

Shoulder pain (WP>15) in the past year was found to be significantly associated with pain today (PT>15) in Head/Neck, Elbow, Hand/Wrist, Low back, Knee, Ankle/Feet, Elbow and Hand/Wrist together, at least 1 UE site, and at least 1 LE site.

Elbow pain (WP>15) in the past year was found to be significantly associated with pain today (PT>15) in Shoulder, Hand/Wrist, Knee, Head/Neck & Shoulder together, Elbow and Hand/Wrist together, at least 1 UE site, and at least 1 LE site.

Hand/Wrist pain (WP>15) in the past year was found to be significantly associated with pain today (PT>15) in Head/Neck, Shoulder, Elbow, Low back, Knee, Ankle/Feet, Head/Neck & Shoulder together, at least 1 UE site, and at least 1 LE site.

Low back (WP>15) in the past year was found to be significantly associated with pain today (PT>15) in Head/Neck, Shoulder, Hand/Wrist, Hip, Knee, Ankle/Feet, Head/Neck & Shoulder together, Elbow and Hand/Wrist together, at least 1 UE site, and at least 1 LE site.

Hip pain (WP>15) in the past year was found to be significantly associated with pain today (PT>15) in Head/Neck, Low back, Knee, Ankle/Feet, Head/Neck & Shoulder together, at least 1 UE site, and at least 1 LE site.

Knee pain (WP>15) in the past year was found to be significantly associated with pain today (PT>15) in Head/Neck, Hand/Wrist, Low back, Hip, Ankle/Feet, Head/Neck & Shoulder together, Elbow and Hand/Wrist together, and at least 1 UE site.

Ankle/Feet pain (WP>15) in the past year was found to be significantly associated with pain today (PT>15) in Head/Neck, Shoulder, Hand/Wrist, Low back, Knee, Head/Neck & Shoulder together, Elbow and Hand/Wrist together, and at least 1 UE site.

3.3.3 Multisite association of pain (WP > 50, PT > 15)

Multisite association of pain adjusted for sex and age across all anatomical sites with their respective confidence intervals is reported in *Table 26*.

Head/Neck pain (WP>50) in the past year was found to be significantly associated with pain today (PT>15) in Shoulder, Hand/Wrist, Low back, Hip, Knee, Ankle/Feet, Elbow and Hand/Wrist together, at least 1 UE site, and at least 1 LE site.

Shoulder pain (WP>50) in the past year was found to be significantly associated with pain today (PT>15) in Head/Neck, Elbow, Hand/Wrist, Low back, Knee, Ankle/Feet, Elbow and Hand/Wrist together, and at least 1 LE site.

Elbow pain (WP>50) in the past year was found to be significantly associated with pain today (PT>15) in Shoulder, Hand/Wrist, Knee, Head/Neck & Shoulder together, and at least 1 LE site.

Hand/Wrist pain (WP>50) in the past year was found to be significantly associated with pain today (PT>15) in Head/Neck, Shoulder, Elbow, Low back, Knee, Ankle/Feet, Head/Neck & Shoulder together, and at least 1 LE site.

Low back pain (WP>50) in the past year was found to be significantly associated with pain today (PT>15) in Head/Neck, Shoulder, Hand/Wrist, Hip, Knee, Ankle/Feet, Head/Neck & Shoulder together, Elbow and Hand/Wrist together, at least 1 UE site, and at least 1 LE site.

Hip pain (WP>50) in the past year was found to be significantly associated with pain today (PT>15) in Head/Neck, Low back, Knee, Ankle/Feet, Head/Neck & Shoulder together, at least 1 UE site, and at least 1 LE site.

Knee pain (WP>50) in the past year was found to be significantly associated with pain today (PT>15) in Head/Neck, Shoulder, Elbow, Hand/Wrist, Low back, Hip, Ankle/Feet, Head/Neck & Shoulder together, Elbow and Hand/Wrist together, and at least 1 UE site.

Ankle/Feet pain (WP>50) in the past year was found to be significantly associated with pain today (PT>15) in Head/Neck, Shoulder, Hand/Wrist, Low back, Hip, Knee, Ankle/Feet, Head/Neck & Shoulder together, Elbow and Hand/Wrist together, and at least 1 UE site.

Chapter 4: Developing a Continuous Severity Scale (CSS) & Using Machine Learning Tools to Identify Job Characteristics to Aid in Model Building

4.1 Introduction

Overly simplified, non-specific case-definitions such as "Presence of pain" may overstate injuries and highly specific diagnostic outcomes (i.e., Lateral Epicondylitis) may understate the true number of injured employees (Cimmino et al., 2011; Harden et al., 2007; Harrington et al., 1998; L. Punnett et al., 2004a; Laura Punnett & Wegman, 2004b; Sluiter' et al., n.d.). However, a continuous case definition that takes into consideration the intensity, duration, treatment seeking patterns and consequences of pain to produce a spectrum of disability ranging from "Little to None (Completely Normal)" to "Completely Disabled" could help correct for these over- or under-diagnoses. A continuous definition of health outcome more realistically models the state that injured persons encounter. Injuries, particularly WMSDs, typically develop gradually and, likewise, heal gradually. A dichotomous injury definition (i.e., "healthy" or "injured") ignores the complex nature of injuries and fails to allow for nuanced investigation of "gray jobs": those jobs that do not appear "very safe" or "very hazardous." In fact, many epidemiological studies create case and control definitions that exclude many of the inter-mediate risk, or "gray" jobs. Similarly, some epidemiological studies have used dual-cut points for risk assessment tool outcomes to create greater separation of data. For example, in studies of the Revised NIOSH Lifting Equation (RNLE), authors will often compare jobs with Lifting Indices (LIs) < 1 to jobs with LIs > 3, ignoring the intermediate risk jobs (LIs between 1 and 3) (Boda et al., 2012; Drinkaus et al., 2005; Marras et al., 1999; Sesek, 2003). A continuous health outcome would allow exploration

of those “gray” jobs whose workers would be expected to fall somewhere on the continuum from “completely normal” to “severely disabled” such as “moderately disabled.”

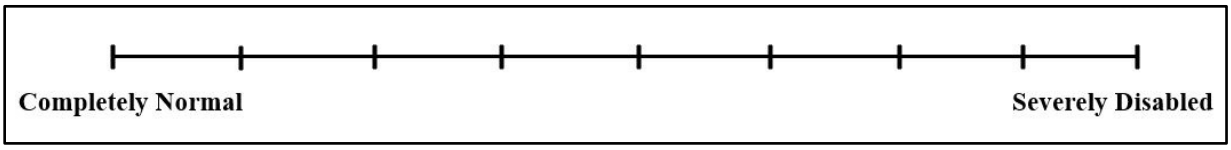

Figure 10: Illustration of a Continuous Severity Scale (CSS)

The ergonomic data [*Appendix 4*] collected by the researchers is essentially a critical analysis of each job. These jobs were further broken down into up to seven tasks and were recorded using a question set that contains over 230 variables, out of which several are categorical variables containing five or more categories. With this amount of detailed information across eight body parts, it is virtually impossible to test associations with each job characteristic and development of WMSD manually. Machine learning (ML) is a tool that utilizes advanced statistical methods and algorithms by analyzing specific patterns to build strong models that predict risk of developing WMSDs without relying on explicit instructions by the user and user biases (Asensio-Cuesta et al., 2010; Suárez Sánchez et al., 2014).

A vast amount of data was collected in the original study of 1998. Another objective of the current study is to develop mathematical models with the help of machine learning tools that can be applied on future studies that are similar in nature. In epidemiological studies, often statistical (mathematical) tools are used to develop predictive models however, the accuracy of these models depend on the pre-processing

carried out before beginning analysis, for example, checking variables for normality and if not normal then selecting and applying appropriate transformations, checking for outliers, and checking for multi-collinearity. This process quickly becomes time-intensive and prone to errors as the number of variables are increased. ML as a tool has been used in epidemiological studies to develop predictive models, (Zurada et al., 1997) and (C. L. Chen et al., 2004; C.-L. Chen et al., 2000) developed models for the prediction of low-back disorders by applying ML algorithms such as Artificial Neural Networks (ANN) on historical databases.

ML algorithms work by generally partitioning the database to be analyzed into two groups – Training and Testing. The algorithms "learn" on the 'Training' section of the database and applies its learning on the 'Testing' section, and then provide a percentage accuracy of its learnings. The goal of this study is to create a 'Training' database so that the appropriate algorithms can be applied and tested on future epidemiological studies. An illustration of this logic is shown in *Figure 11.*

In this study IBM SPSS Modeler v18.0 will be used to apply various ML algorithms such as *Linear Regression*, *C&R Tree*, *CHAD*, and *Decision Tree* to develop models that can serve as a 'Training' model, to be applied on future studies.

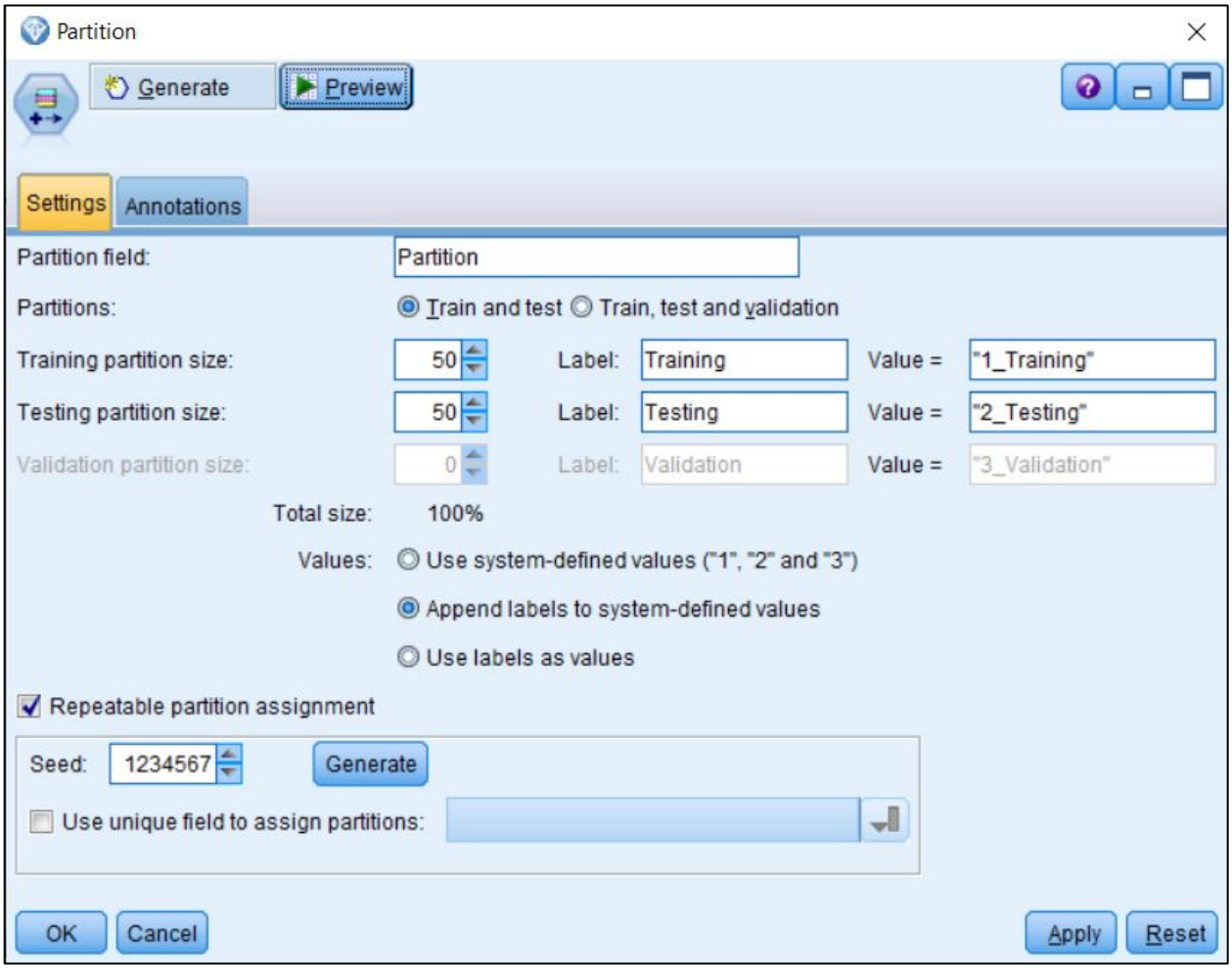

Figure 11: Illustration of Data Partitioning in SPSS Modeler v.18

4.2 Methods

4.2.1 Continuous Severity Scale (CSS)

Since our outcome is a continuous severity scale, it is necessary to aggregate tasks by converting categorical type data into a continuous set of data. This is accomplished by summing up exposure for a category across all tasks for a given job. For example, consider employee *X*, performing job 6017. Three tasks are analyzed for job **6017**; "Task1, Task2, and Task 3". In Task 1, the employee grips an object with a grip value = **1** (Wrap Grip) for 100 repetitions, in Task 2, the employee grips an object with a grip value = **4** (Oblique Grip) for 50 repetitions, and in Task 3, the employee grips an object with a grip value = **1** (Wrap Grip) for 25 repetitions.

Table 26: Data Preparation to Develop CSS - A

Job ID	Task	Grip Position	Reps
6017	1	1	100
6017	2	4	50
6017	3	1	25

Then, employee *X* performs a total of 125 repetitions in a “Wrap Grip” and 50 repetitions in an “Oblique Grip” for job 6017.

Table 27: Data Preparation to Develop CSS - B

Job ID	Grip Position						
	1	2	3	4	5	6	7
	Repetitions						
6017	125	0	0	50	0	0	0

Initially, a proposed method to develop a CSS was by breaking down the selected parameters into categories and assigning weights proportional to an increase in the severity of the parameters. The selected parameters are a) *Point prevalence of intensity of pain*, b) *Worst possible intensity of pain*, c) *Number of episodes of pain*, d) *Duration of each episode of pain*, e) *Treatment seeking patterns*, and f) *Resulting lost work time OR placement on light/restricted duty*. *Table 27* describes the categories:

Table 28: Weighted Categories to enable development of CSS

Weights	**0**	**10**	**20**	**30**	**40**	**50**
Pain Today	PT=0	0 < PT <=10	10 < PT <= 25	25 < PT <= 50	50 < PT <= 75	PT >= 75
Worst Pain	WP=0	0 < WP <=10	10 < WP <= 25	25 < WP <= 50	50 < WP <= 75	WP >= 75
No. of episodes	0	<= 12	12 < No. <= 52	52 < No. <= 104	104 <= No. < 365	No. = 365
Duration	0	1 hr <= Dur <= 1 day	1 day to 1 week	1 week < Dur. <= 1 month	1 month < Dur. <=3 months	Dur. >= 3months
FTOV	0	1	2	3	4	>4
Restricted Duty & LWT	0	1 day < LWT < 1 week	1 week <= LWT < 1 month	1 month <= LWT < 3 months	3 Months <= LWT < 6 months	LWT >= 6 months

This proposed "**Method 1"** scale generated a continuous outcome of severities ranging from a minimum value of 0 to a maximum value of 300. For example, if an employee *X* indicates that his 'Pain Today' = 15, 'Worst Pain' = 70, experiences pain once a week ('Number of episodes' = 52), the pain lasts for a couple of days ('Duration' = 2 days), sought treatment 3 times in the past year ('FTOV = 3'), and was placed on a restricted duty for 2 weeks ('LWT = 2 weeks) then the severity score was be calculated as shown in *Figure 12*.

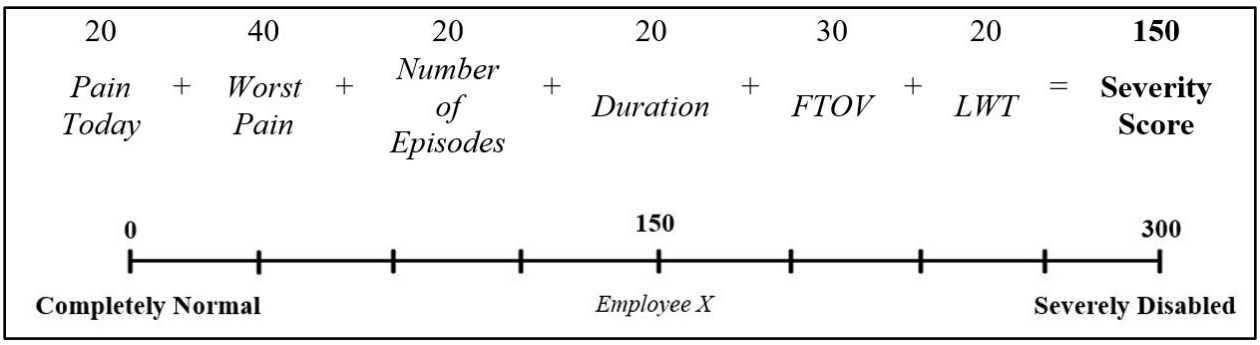

Figure 12: Example of Calculating CSS

A CSS using the above proposed method was calculated across all anatomical sites for employees who experienced musculoskeletal pain and disc discomfort. Histograms displaying the distribution of the CSS scores across all anatomical sites are shown below (*Figures 13 – 20*).

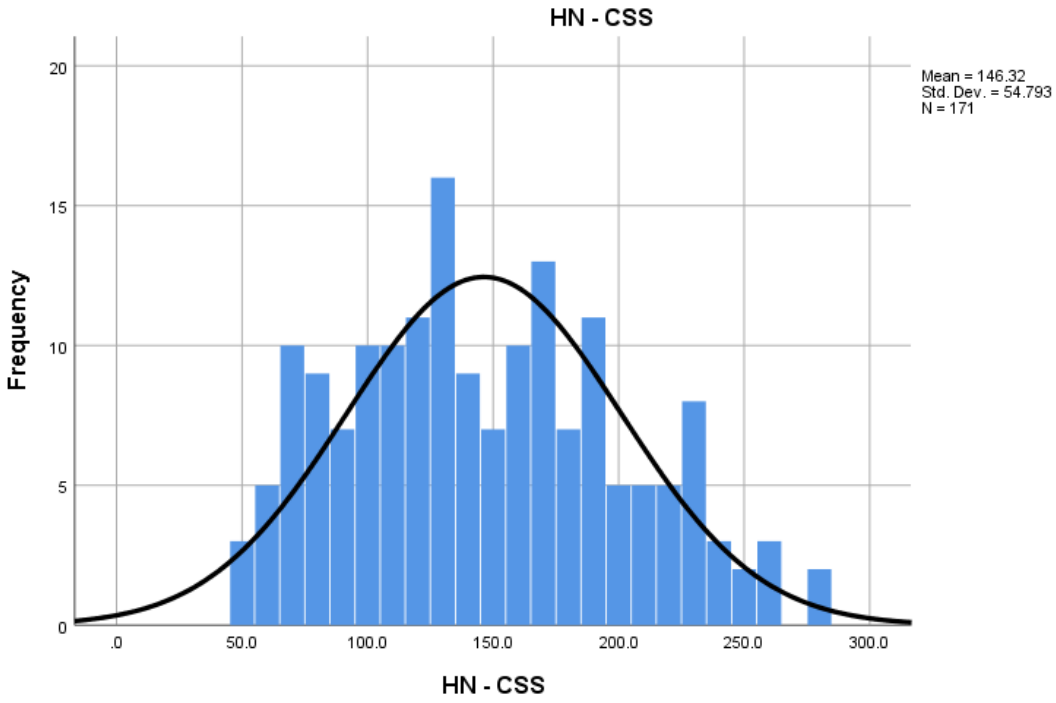

Figure 13: Distribution of Head/Neck CSS using Method 1

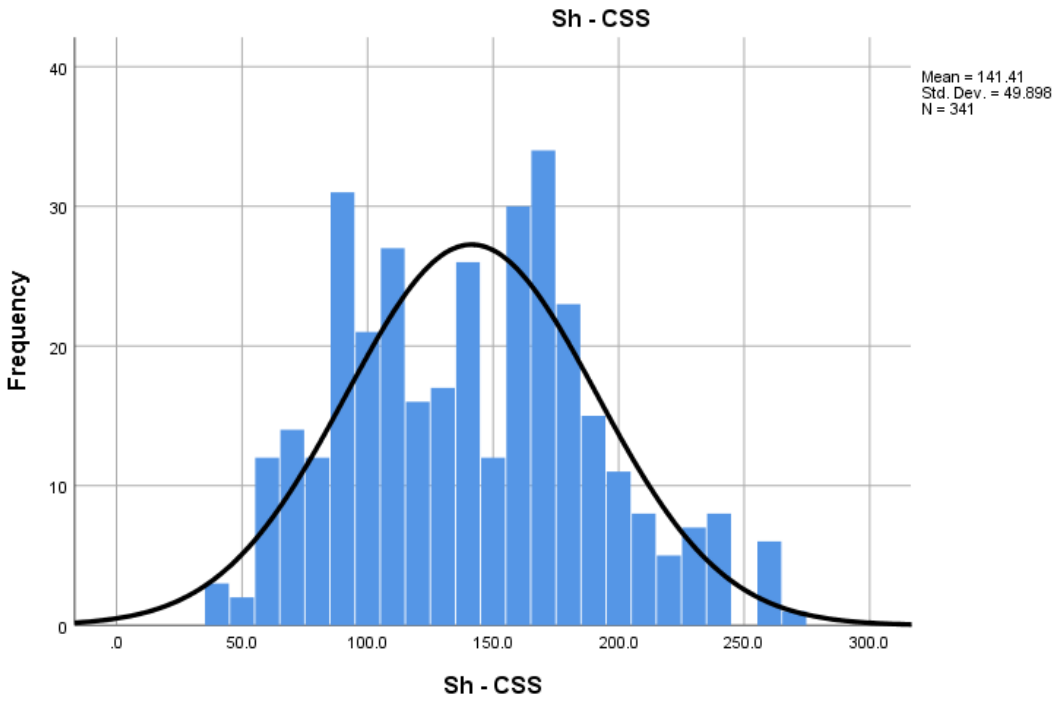

Figure 14: Distribution of Shoulder CSS using Method 1

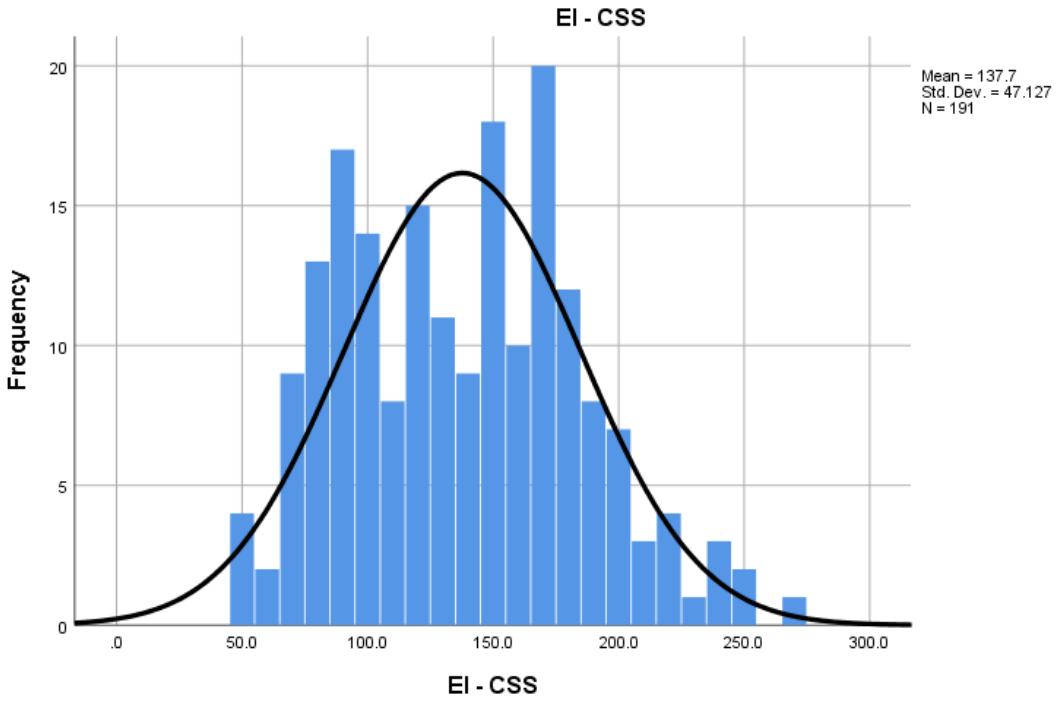

Figure 15: Distribution of Elbow CSS using Method 1

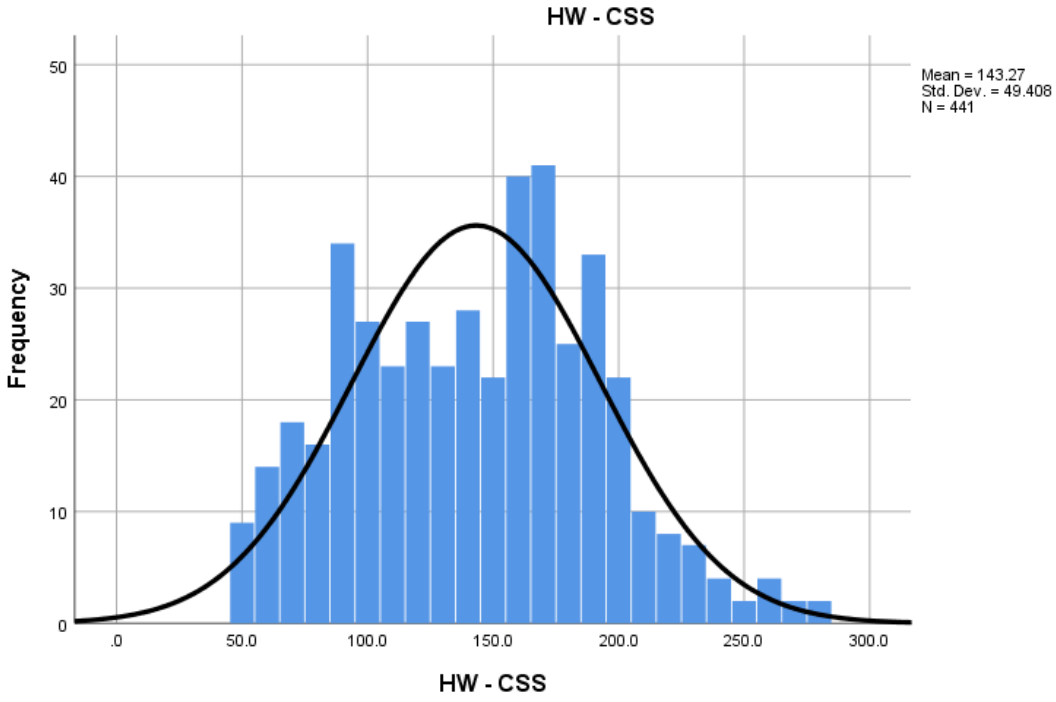

Figure 16: Distribution of Hand/Wrist CSS using Method 1

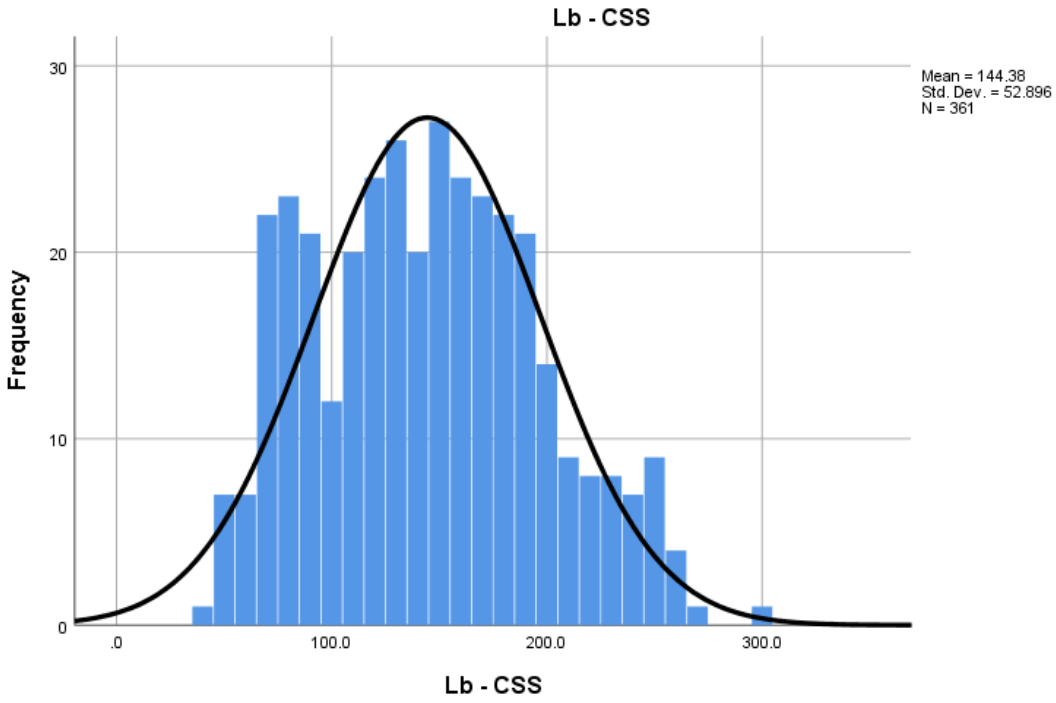

Figure 17: Distribution of Low Back CSS using Method 1

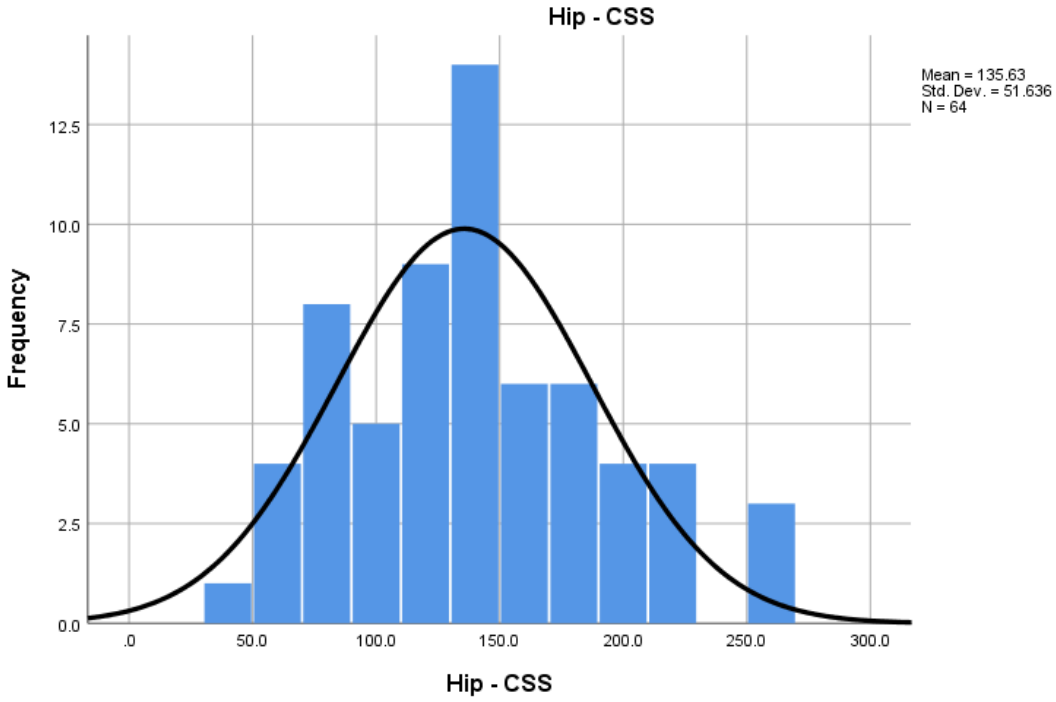

Figure 18: Distribution of Hip CSS using Method 1

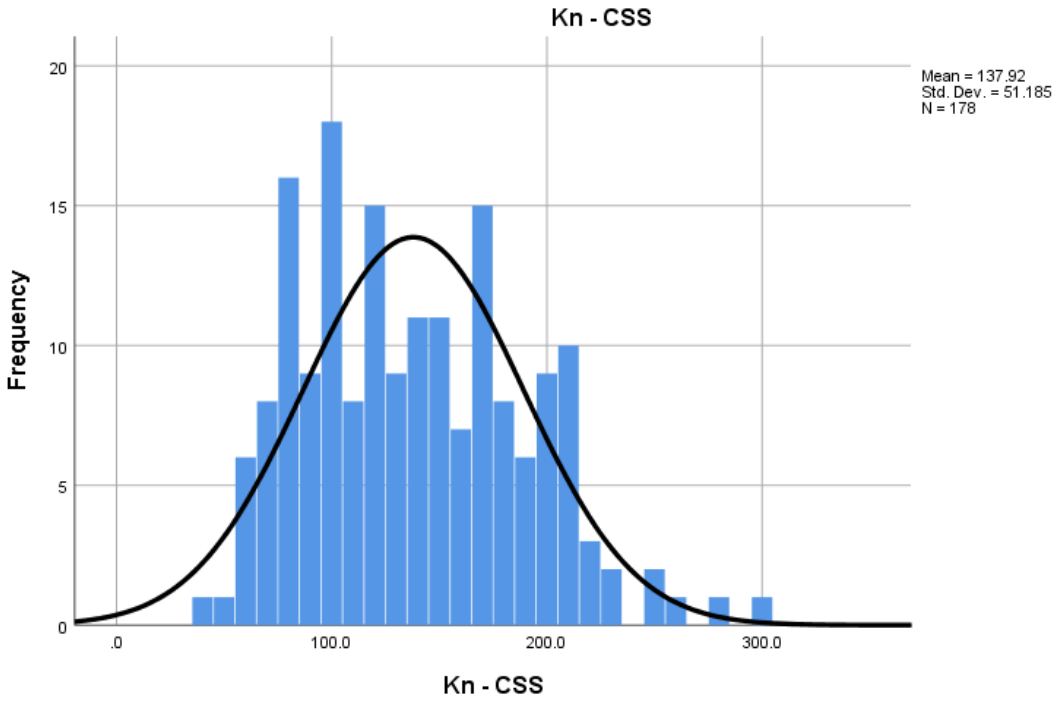

Figure 19: Distribution of Knee CSS using Method 1

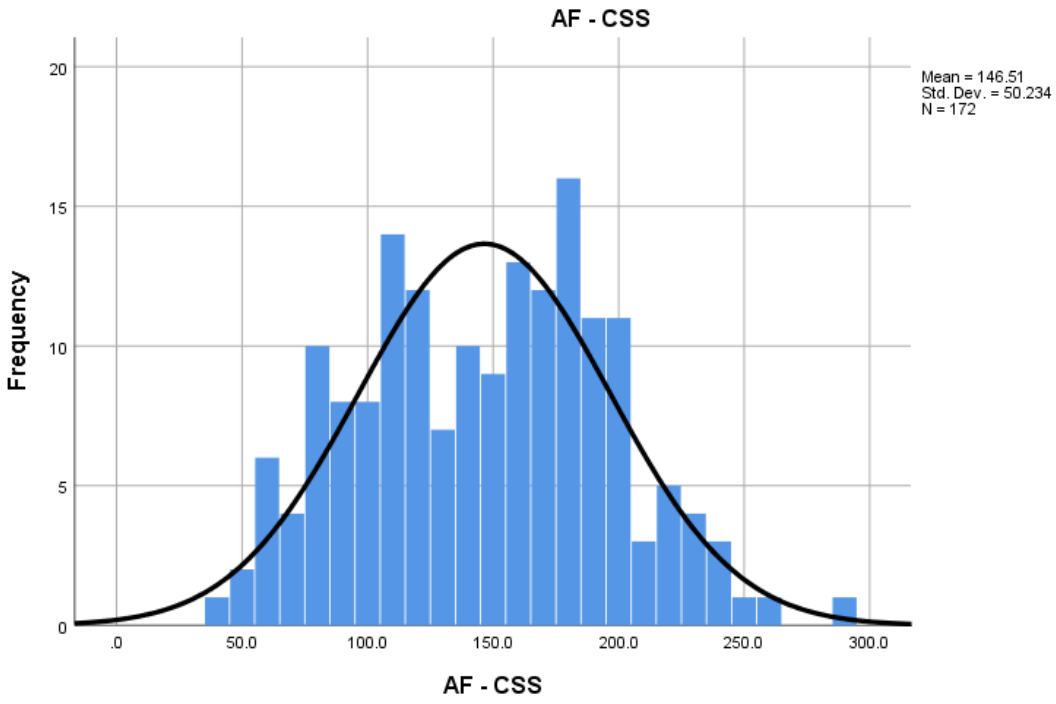

Figure 20: Distribution of Ankle/Feet CSS using Method 1

However midway in analyses, a decision was taken to create a new CSS without using arbitrary weights by performing simple addition of all outcomes – This was "**Method 2**", all further analyses were carried out using this method. For example, if an employee *X* indicates that his 'Pain Today' = 15, 'Worst Pain' = 70, experiences pain once a week ('Number of episodes' = 52), the pain lasts for a couple of days ('Duration' = 2 days), sought treatment 3 times in the past year ('FTOV = 3'), and was placed on a restricted duty for 2 weeks ('LWT = 2 weeks) then the severity score will be calculated as follows:

15		70		52		2		3		14		**156**
Pain Today	+	*Worst Pain*	+	*Number of Episodes*	+	*Duration*	+	*FTOV*	+	*LWT*	=	**Severity Score**

Figure 21: Example of Calculating CSS using Method 2

Pearson correlation was run between the new CSS (Method 2) and WP in the last year. CSS across all anatomical sites were significantly correlated with WP in the last year. CSS developed by method 1 and method 2 were also significantly correlated with each other as well as with WP in the last year. "Method 2" was developed and used to eliminate the need of assigning arbitrary weights. Results from the correlation analyses are as follows:

The correlation between Head/Neck – Worst Pain and Head/Neck – Continuous Severity Scale is significant ($r = 0.349$, $p < 0.01$). The correlation between Shoulder – Worst Pain and Shoulder – Continuous Severity Scale is significant ($r = 0.256$, $p < 0.01$). The correlation between Elbow – Worst Pain

and Elbow – Continuous Severity Scale is significant ($r = 0.319$, $p < 0.01$). The correlation between Hand/Wrist – Worst Pain and Hand/Wrist – Continuous Severity Scale is significant ($r = 0.326$, $p < 0.01$). The correlation between Low back – Worst Pain and Low back – Continuous Severity Scale is significant ($r = 0.331$, $p < 0.01$). The correlation between Hip – Worst Pain and Hip – Continuous Severity Scale is significant ($r = 0.364$, $p < 0.01$). The correlation between Knee – Worst Pain and Knee – Continuous Severity Scale is significant ($r = 0.346$, $p < 0.01$). The correlation between Ankle/Feet – Worst Pain and Ankle/Feet – Continuous Severity Scale is significant ($r = 0.449$, $p < 0.01$).

Histograms displaying the distribution of the CSS scores calculated using "**Method 2**" across all anatomical sites are shown below (*Figures 22 – 29*).

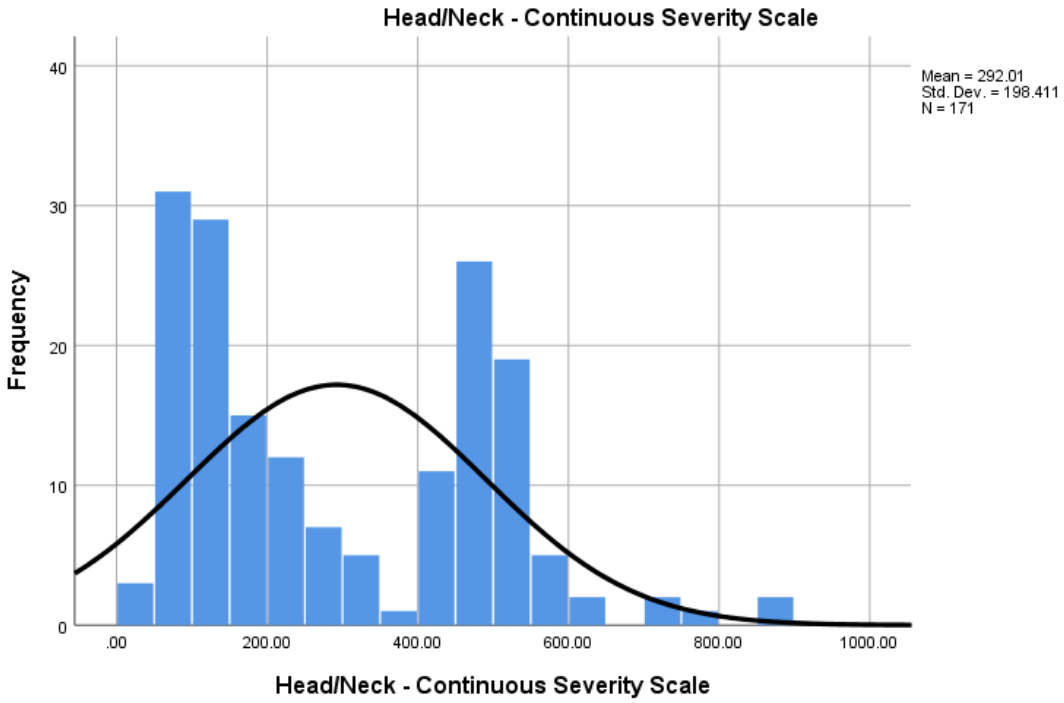

Figure 22: Distribution of Head/Neck CSS using Method 2

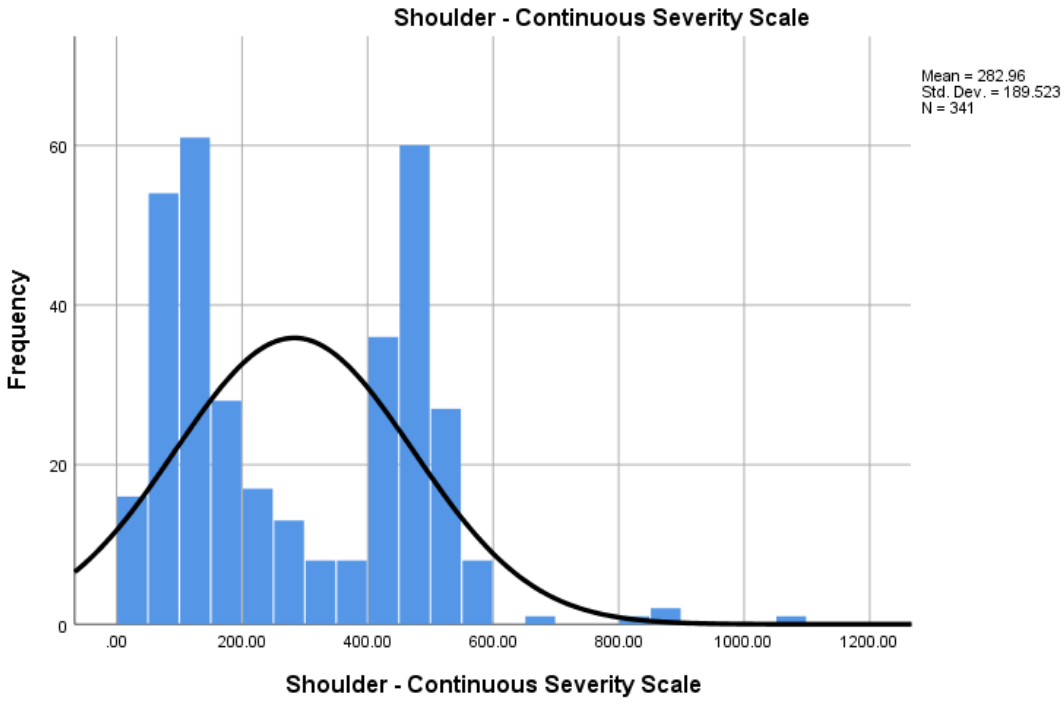

Figure 23: Distribution of Shoulder CSS using Method 2

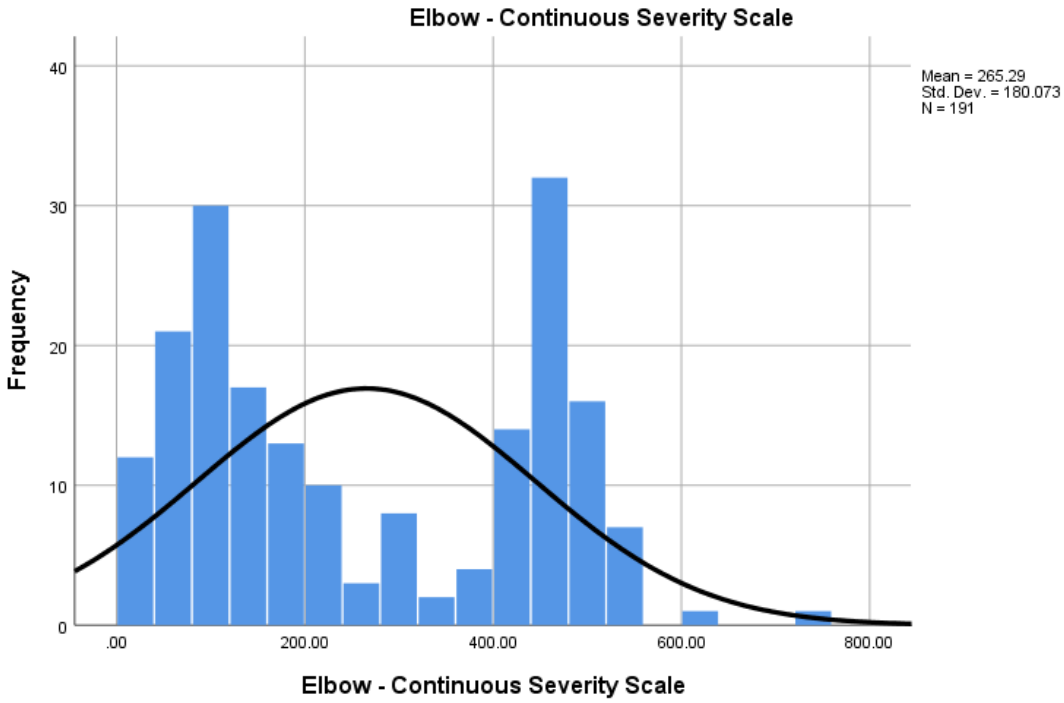

Figure 24: Distribution of Elbow CSS using Method 2

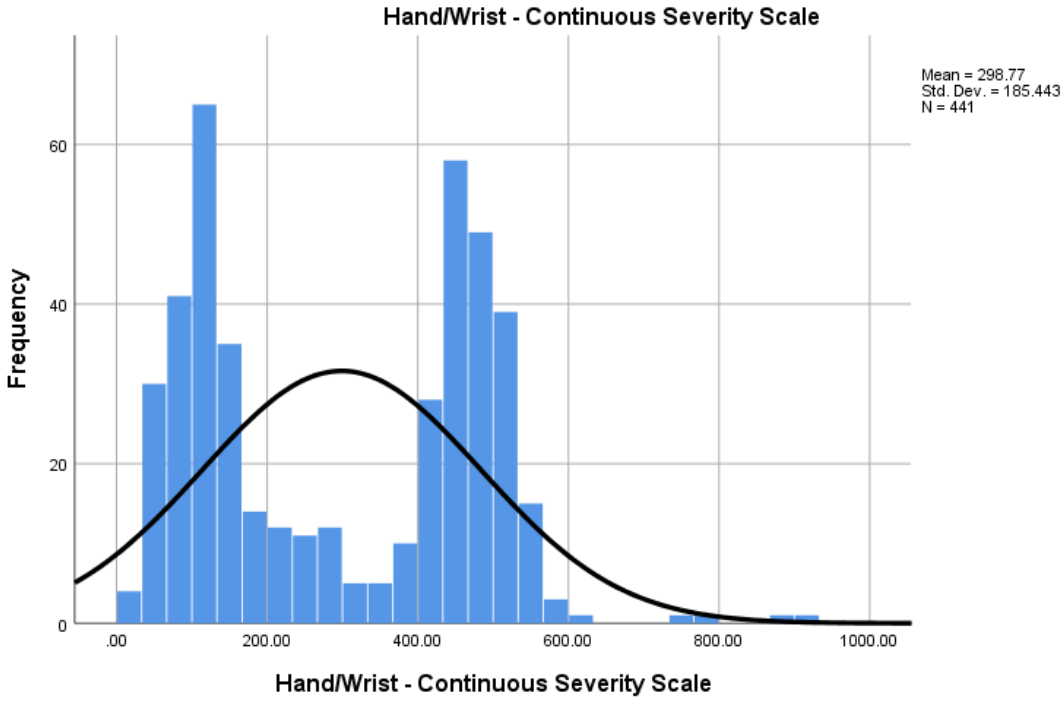

Figure 25: Distribution of Hand/Wrist CSS using Method 2

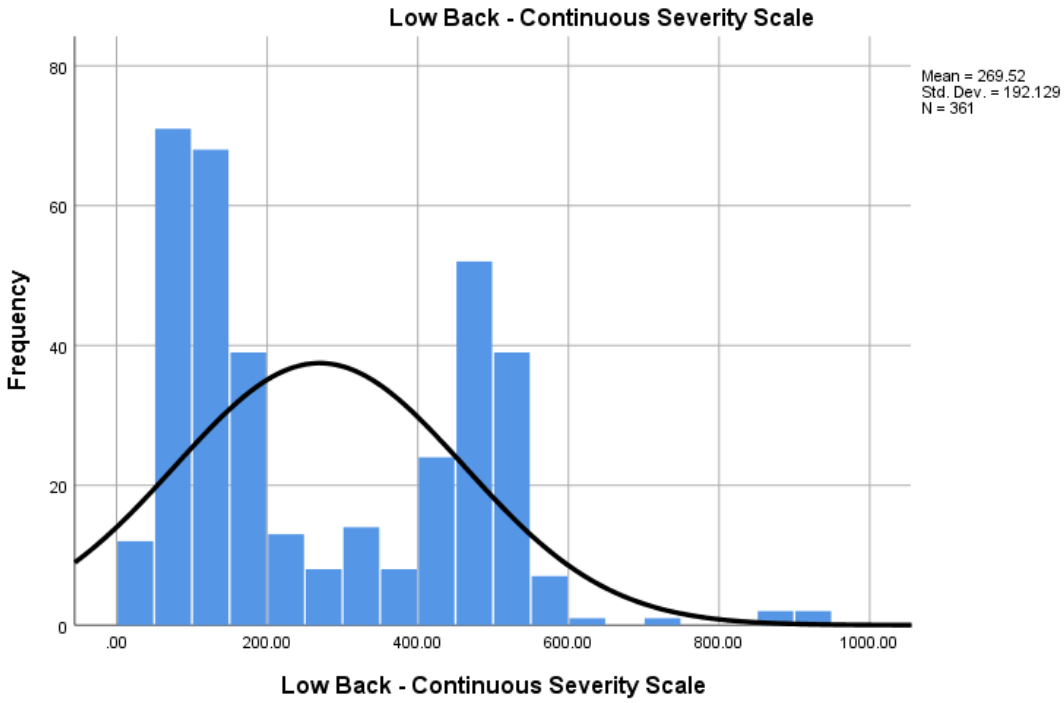

Figure 26: Distribution of Low Back CSS using Method 2

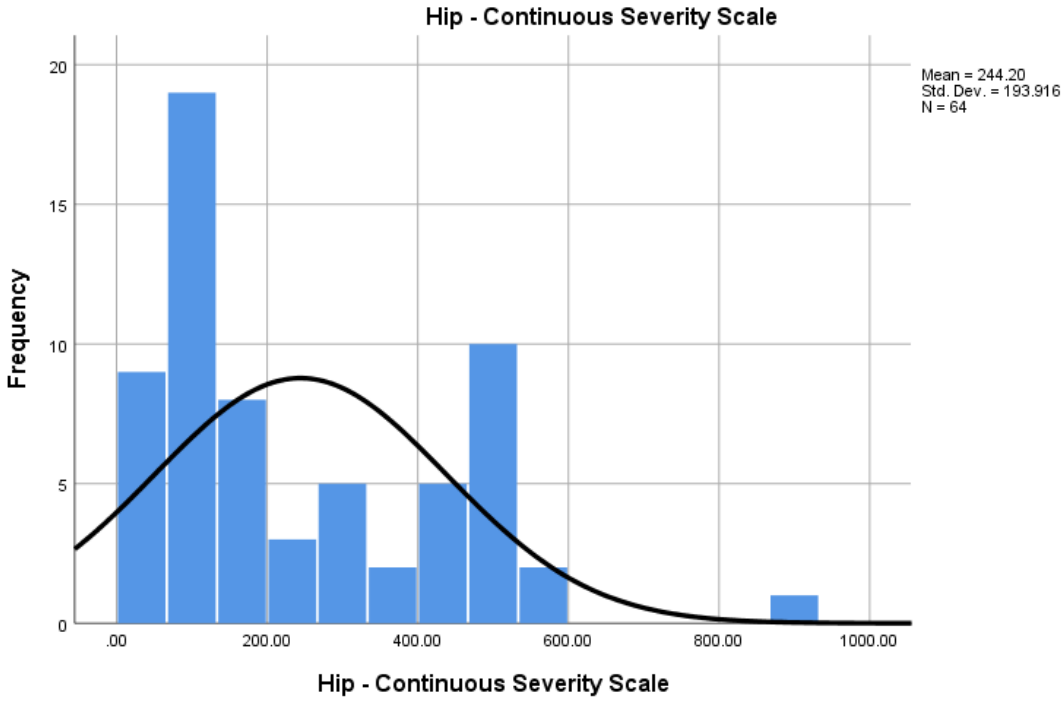

Figure 27: Distribution of Hip CSS using Method 2

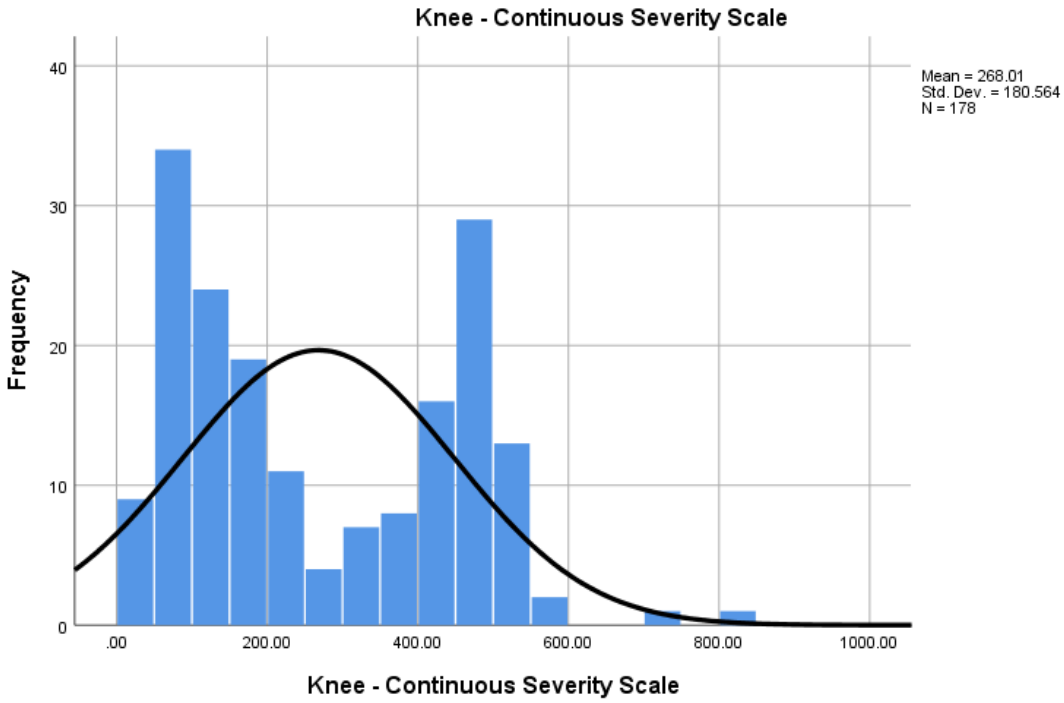

Figure 28: Distribution of Knee CSS using Method 2

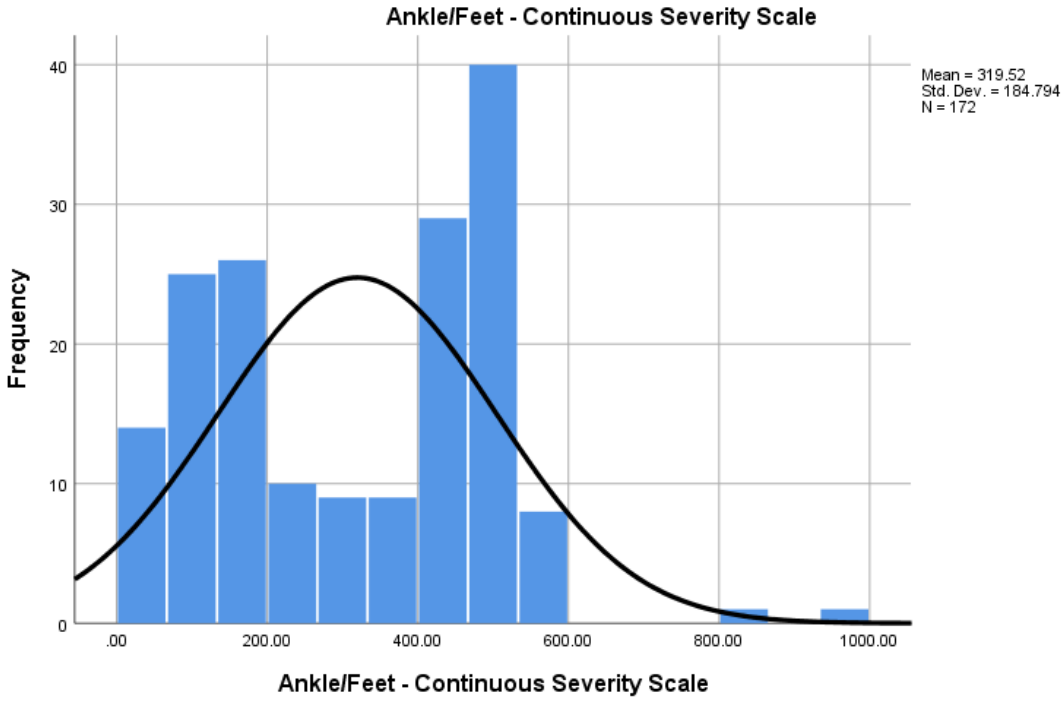

Figure 29: Distribution of Ankle/Feet CSS using Method 2

4.2.2 Building models using ML tools

IBM SPSS Modeler v18.0 was used as a software tools to develop 'Training' models. *Figure 30* provides a visual representation of the progression of steps and logic.

The steps involved in this process are as follows:

1) **Data Input Node**

   This node is used to upload the data to be analyzed to the program in either an MS Excel (.xlsx) file or an SPSS Statistics file (.sav).

2) **Data Inspection Node**

   This node allows the user to check the uploaded data for outliers, missing values and classification of the data type, i.e., if the program accurately classified the data according to its type (categorical, continuous, nominal, etc.).

3) **Defining Data Type Node**

   This node is used to define the target variable (Dependent variable (DV)), Independent Variable (IV), override the data type and allows the user to filter variables if required.

4) **Data Partition Node**

   The program randomly partitions the data into two equal, 'Training' and 'Testing' datasets. 'Training' data is where the program identifies and learns the association between the DV and IV's and applies this learning on the 'Testing' dataset to validate its learnings. The user can define the partitioning of the datasets other than the default 50-50 partitioning. The overarching goal

of this experiment is to conduct prospective studies by collecting similar data and applying the learnings from the current dataset. For example, the entire current dataset will serve as 'Training' data and the learnings will be applied to data collected in the future to validate the developed predictive models.

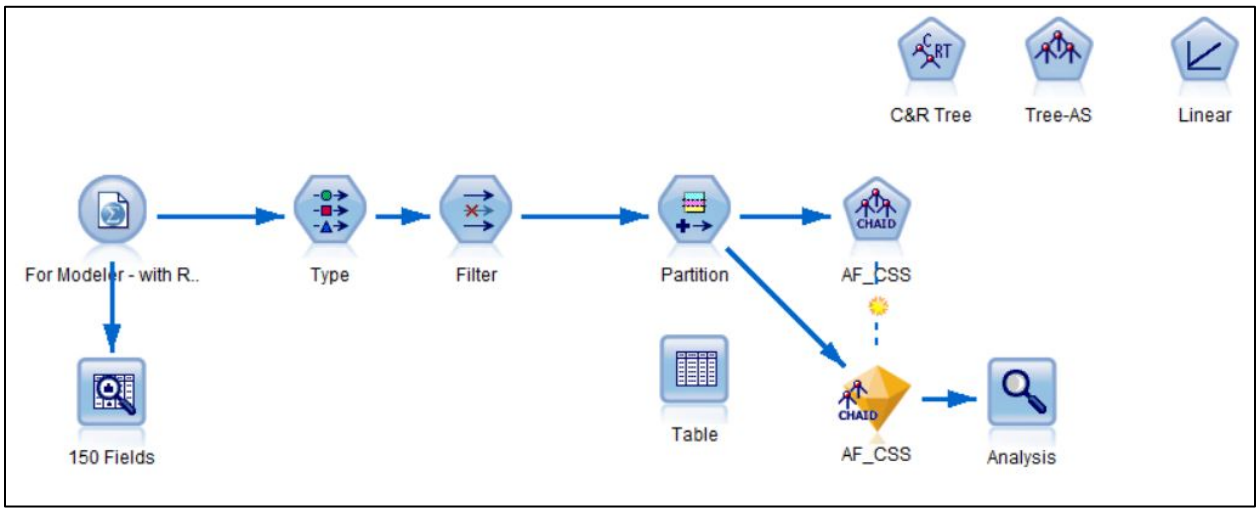

Figure 30: Visual Representation of the ML process

5) Results and Analysis Node

Individual predictor variables, significance, and model accuracy can be viewed from this node.

Four algorithms were selected for testing: a) *Linear Regression*, b) *C&R Tree*, c) *CHAID*, and d) *Decision Tree.* The yellow diamond shown in *Figure 30* is a node that represents a built model and called as a "gold nugget".

4.3 Results

Accuracy of models built with the ML algorithms across all anatomical sites with the CSS as a dependent variable is reported in *Table 30*. Model accuracy is reported for both, the 'Training' phase, and the 'Testing' phase. Each algorithm was applied twice – One that allowed variables that make up the CSS (outcomes such as WP, PT, FTOV, restricted duty, and LWT) and another without the outcomes.

All algorithms performed exceptionally in building models with the outcomes included across all anatomical sites. The lowest 'Testing' model accuracy was 84% and most of the models had an accuracy over 91%. The algorithm, *C&R Tree* failed to create models for Hip, and the algorithm *Decision Tree* failed to create models for Elbow, Hip, Knee, and Ankle/Feet.

Most of the algorithms did not perform well without the outcomes included. *Linear Regression* performed well as compared to other algorithms with the highest 'Testing' accuracy of 46%. However, all algorithms had a comparatively accurate 'Training' models. Such a result is likely due to partitioning the data in two equal parts (50 – 50) and further strengthens the assumption that more data [and/or] studies are required to build models that can accurately predict WMSDs.

Figure 31 provides an illustration on the various combination of partition when multiple databases (studies) can be used to build even more robust models. ML is an efficient tool to analyze epidemiological studies and create models, these models will only get better when more amount of data is provided.

Table 29: Model Accuracy of 'Training' Models Across all Anatomical Sites

Anatomical Sites	Linear Regression				C&R Tree				CHAID				Decision Tree			
	w Outcomes		w/o Outcomes		w Outcomes		w/o Outcomes		w Outcomes		w/o Outcomes		w Outcomes		w/o Outcomes	
	Training	Testing	Training	Testing	Training	Testing	Training	Testing	Training	Testing	Training	Testing	Training	Testing	Training	Testing
Head/Neck	99%	97%	83%	35%	97%	97%	--	--	100%	92%	89%	29%	97%	97%	0%	0%
Shoulder	98%	96%	78%	46%	94%	93%	66%	38%	98%	94%	80%	34%	89%	87%	31%	17%
Elbow	99%	95%	78%	16%	99%	97%	--	--	100%	97%	75%	6%	--	--	--	--
Hand/Wrist	99%	98%	57%	32%	98%	98%	51%	16%	97%	97%	62%	18%	86%	91%	30%	24%
Low Back	98%	95%	75%	45%	96%	93%	45%	37%	98%	91%	67%	25%	84%	86%	34%	18%
Hip	99%	96%	92%	36%	--	--	--	--	99%	88%	--	--	--	--	--	--
Knee	99%	96%	79%	5%	98%	94%	0%	0%	100%	94%	93%	6%	--	--	--	--
Ankle/Feet	99%	91%	83%	12%	96%	84%	--	--	99%	93%	69%	10%	--	--	--	--

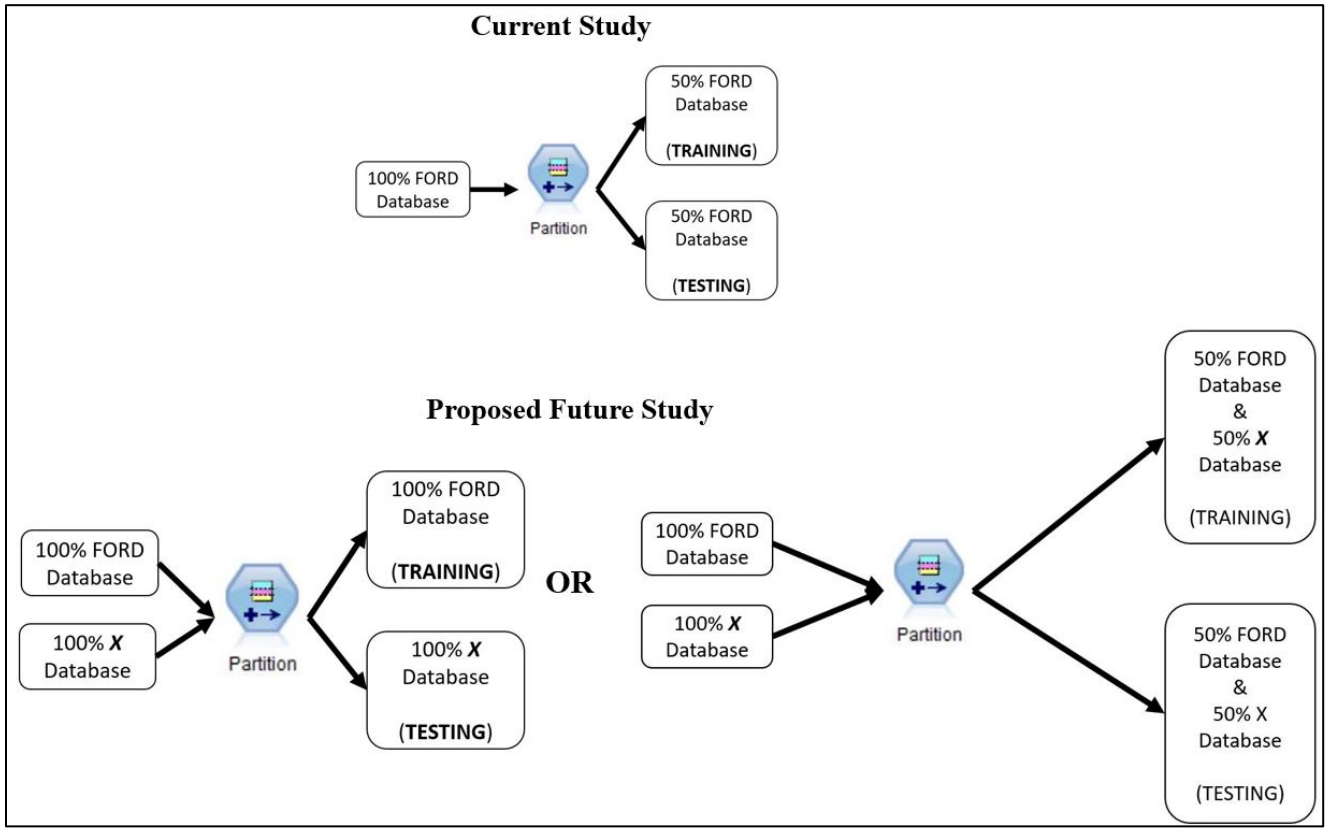

Figure 31: Illustration of Partitioning Logic with Multiple Databases

Chapter 5: Conclusion & Discussion

5.1 Result Summary

Results from the above studies are grouped by anatomical sites and are summarized below.

5.1.1 Head/Neck

Overall prevalence of Head/Neck pain and discomfort in the study population was 17%, out of which 60% of the subjects indicating Head/Neck Pain were males and 40% were females. Of the subjects with Head/Neck pain, 76% had at least one clinic visit due to the pain and discomfort. Sex, age, high BMI, presence of previously diagnosed conditions, involvement of outside work activities, RPE, shift worked, high job demand, low job control, high job strain, low job satisfaction, and pain at other sites were significantly associated with the pain and discomfort in Head/Neck.

5.1.2 Shoulder

Overall prevalence of Shoulder pain and discomfort in the study population was 33%, out of which 66% of the subjects indicating Shoulder pain were males and 34% were females. Of the subjects with Shoulder pain, 62% had at least one clinic visit due to the pain and discomfort. Sex, years of experience, presence of previously diagnosed conditions, RPE, shift worked, high job demand, high job strain, low job satisfaction, and pain at other sites were significantly associated with the pain and discomfort in Shoulder.

5.1.3 Elbow

Overall prevalence of Elbow pain and discomfort in the study population was 19%, out of which 72% of the subjects indicating Elbow pain were males and 28% were females. Of the subjects with Elbow pain, 58% had at least one clinic visit due to the pain and discomfort. Age, high BMI, presence of previously diagnosed conditions, shift worked, high job demand, high job strain, low job satisfaction, and pain at other sites were significantly associated with the pain and discomfort in Elbow.

5.1.4 Hand/Wrist

Overall prevalence of Hand/Wrist pain and discomfort in the study population was 43%, out of which 63% of the subjects indicating Hand/Wrist pain were males and 37% were females. Of the subjects with Hand/Wrist pain, 60% had at least one clinic visit due to the pain and discomfort. Sex, age, presence of previously diagnosed conditions, high job demand, high job strain, low job satisfaction, and pain at other sites were significantly associated with the pain and discomfort in Hand/Wrist.

5.1.5 Low Back

Overall prevalence of Low Back pain and discomfort in the study population was 35%, out of which 69% of the subjects indicating Low Back pain were males and 31% were females. Of the subjects with Low Back pain, 83% had at least one clinic visit due to the pain and discomfort. Age, smoking status, years of experience, presence of previously diagnosed conditions, involvement in outside work activities, RPE, high

job demand, high job strain, low job satisfaction, and pain at other sites were significantly associated with the pain and discomfort in Low Back.

5.1.6 Hip

Overall prevalence of Hip pain and discomfort in the study population was 6%, out of which 64% of the subjects indicating Hip pain were males and 36% were females. Of the subjects with Hip pain, 72% had at least one clinic visit due to the pain and discomfort. Years of experience, presence of previously diagnosed conditions, high job demand, high job strain, low job satisfaction, and pain at other sites were significantly associated with the pain and discomfort in Hip

5.1.7 Knee

Overall prevalence of Knee pain and discomfort in the study population was 17%, out of which 69% of the subjects indicating Knee pain were males and 31% were females. Of the subjects with Knee pain, 61% had at least one clinic visit due to the pain and discomfort. Age, presence of previously diagnosed conditions, RPE, high job demand, high job strain, low job satisfaction, and pain at other sites were significantly associated with the pain and discomfort in Knee.

5.1.8 Ankle/Feet

Overall prevalence of Ankle/Feet pain and discomfort in the study population was 35%, out of which 69% of the subjects indicating Ankle/Feet pain were males and 31% were females. Of the subjects with Ankle/Feet pain, 83% had at least one clinic visit due to the pain and

discomfort. High BMI, presence of previously diagnosed conditions, RPE, high job demand, high job strain, low job satisfaction, and pain at other sites were significantly associated with the pain and discomfort in Ankle/Feet.

5.2 Discussion

This current study was possible due to a proposal sent out by the UAW-Ford NJCHS. Of the 11 studies identified in the automotive industry by conducting a systematic literature review, 2 came from UAW-Ford again, 2 from UAW-General Motors (GM), and 1 from UAW-Chrysler. Others were independent studies conducted in small manufacturing facilities or by simulating automotive work in a laboratory setting, and one review study conducted by (Hausmanninger et al., 2019). Of the studies identified, 5 were cross sectional in nature and 5 had a prospective study design.

5.2.1 Cross Sectional Studies

Gold et al. 2005 conducted a cross-sectional study with an affiliation to UAW-Ford on 1174 participants to study association between ergonomic stressors and self-reported vibration threshold measured by a Borg scale on head/neck, shoulder, and UE. They identified predictors such as high hand force, whole body vibration, awkward posture , and contact stress. However, the study did not consider personal risk factors of the employee affecting the vibration threshold score.

Carnide et al. 2006 conducted an independent cross-sectional study to understand the interaction of biomechanical and morphological risk factors on shoulder workload on 29 participants. They did not find conclusive evidence of the interaction with presence of pain being the only significant predictor. This study did make an attempt to study a combination of the personal characteristics but only in one body part.

Seamana et al. 2010 conducted a cross-sectional study on 79 participants to study effect of biomechanical load on shoulder pain. They concluded that awkward posture, peak load, and cumulative load were predictors for shoulder pain. This study only focused on shoulder and did not consider the role of other risk factors that may be associated with shoulder pain.

Varirad et al. 2015 conducted a cross-sectional study on 758 employees to study interaction of physical and occupational factors on days absent due to sickness. They identified risk factors such as shift work, bending, twisting, lifting, and vibration. One of the strengths of this study is that it considered all anatomical segments but failed to consider other risk factors that contributed to sickness that results into days absent.

5.2.2 **Prospective Studies**

Punnett et al. 2004 conducted a study with an affiliation to UAW-Ford on 820 participants to study associations between ergonomic stressors and upper extremity disorders. They found associations after a one-year follow-up between risk factors such as gender, previous UE injury, high job demand, high BMI, and change of job responsibilities on UE pain and discomfort in the last year. They

did successfully identify multiple risk factors but only on UE and not other major body segments.

Werner et al. 2005 conducted a study with an affiliation to UAW-GM on 279 participants to identify risk factors for visiting the medical department (FTOV) because of UE disorders. They identified risk factors such as American Conference for Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV's), diagnoses of Carpal Tunnel Syndrome (CTS), diagnoses of elbow tendonitis, diabetes, and age over 40 years. However, the major focus was only UE, they did not consider other possible risk factors such as psychophysical and psychosocial risk factors. This current study does have data on the application of various ergonomic tools such as the Revised NIOSH Lifting Equation (RNLE), Strain Index (SI), ACGIH TLV, and the OSHA checklist but, the variables associated with tool application were outside of the scope of the current study and future research can be conducted to verify and validate the application of ergonomic tools.

Gold et al. 2006 conducted a study with an affiliation to UAW-Chrysler on 519 participants to study pressure pain thresholds and UE disorders. They identified factors such as gender, grip strength, pain severity, functional impairment score. The case-definition used for this study was UE pressure pain threshold, which is different from other standard case definitions such as FTOV, lost-work time of pain in the last year and further research is required to study the correlation between pressure pain threshold and true pain experience by an

employee/participant. Moreover, other major body parts were not studied which were addressed by the current study.

El Ahrache and Imbeau 2009 conducted a prospective study on 7 participants to compare rest allowance models for static muscular work. This was a simulated study with a focus on shoulder only. They found that the shoulder requires more rest than other muscle groups. Studying rest-allowance and healing is listed as one of the future scope of this current study. Although the importance of rest-allowance on muscle recovery and healing is widely known in the ergonomics and epidemiology community, results based on a study with a n=7 remain inconclusive.

5.2.3 Study 1: Pain & Discomfort – Prevalence, Characteristics, Consequences, and Risk Factors.

The purpose of conducting this study was to verify that etiology for WMSDs involve a complex combination and interaction of multiple risk factors. Odds Ratios (OR's) were used to identify relationships between multiple risk factors and pain or discomfort experienced at a particular body part. An OR is a probability of an event occurring in a group that is exposed (in our case, those experiencing pain and discomfort) divided by the probability of an event occurring in other group (in our case, those who did not experience pain and discomfort). Simply put, an OR is a measure of association between an exposure and an outcome. Since the original study was cross-sectional in nature, it is

difficult to establish exact causal factors which is why association is used, and OR's are valid measure of association in cross-sectional type of studies (Grimes & Schulz, 2008). Primarily there are three statistical cut points involving OR's and the way to interpret them is well put by (Szumilas, 2010):

1. If OR=1, the exposure does not affect the odds of outcome
2. If OR>1, the exposure is associated with higher odds of outcome
3. If OR<1, the exposure is associated with lower odds of outcome

Further, an OR is often reported with a 95% confidence interval (CI) and a *p-value.* CI is used to determine the precision of the obtained OR. A large range of CI often indicates a low level of precision and a small CI or a "tight" CI indicates a high level of precision. A *p-value* is used to determine statistical significance, a *p-value* < 0.05 was deemed statistically significant for all tests conducted in this study.

Results from this study are shown in tables *17* through *19.* Statistically significant associations were found between multiple risk factors across all body parts. The effect of individual, psychophysical, psychosocial, and psychological risk factors on work-related pain and discomfort experienced by employees cannot be ignored and need to be taken into consideration when identifying the root cause of an injury at the workplace and in designing effective interventions.

5.2.4 **Study 2: Multisite Association of Pain**

Results from this study indicate that there exist significant associations among pairs of anatomical sites with discomfort and pain. Motivation to analyze these relationships stemmed from a prior understanding of biomechanical risk factors where muscles from multiple body segments are recruited to perform a particular task, eg., A "pulling" task may affect the back and some upper extremity body parts. Another possible understanding was that pain and discomfort experienced at an anatomical site may affect the entire kinetic chain. For example, pain at right hip may affect the right knee and the right ankle/foot. Additionally, there is another phenomenon that might be at work which involves a physiological response involving systemic inflammation arising from localized pain and discomfort. Results shown in *Table 25* and *Table 26* might be explained by a one or a combination of the three conditions explained above.

Findings from this study can be used by ergonomists and safety/health professionals in the automotive manufacturing industry to understand employee complaints of pain and discomfort. One application of these results would be to assign "light" or "medium" duty work to employees returning to work after an injury. For example, it would be advised that an employee returning from a hip injury be placed on a "light" duty job involving upper extremity tasks rather than a manual material handling or a lifting task.

5.2.5 Study 3: Developing a Continuous Severity Scale (CSS) & Using Machine Learning Tools to Aid in Building a Base 'Training' Model

Machine Learning consists of programs or algorithms that learn from experience and are designed to improve their performance over time. Several machine learning algorithms exist and are used for a variety of reasons including statistical testing, data optimization, generating predictive models, and pattern recognition. The selection of these algorithms is dependent on multiple factors such as the size of data, nature of data, and the complexity of the dataset being analyzed (T. M. Mitchell, 1997; van Leeuwen, 2004). Each algorithm is designed with a specific goal in mind and have their own characteristic advantages and disadvantages. Further, each algorithm works on certain underlying assumptions and criteria's that need to be fulfilled before applying them. Due to these reasons, it is possible that their individual accuracy may vary depending on the type of data being analyzed and the way an algorithm is applied (Uddin et al., 2019).

The purpose of this study was to, a) propose a continuous severity scale that moves away from dichotomous case definitions, and b) to simply show the feasibility of using ML algorithms to assist in building predictive models from epidemiological databases.

The four algorithms used in this study were solely selected on their ability to analyze the type of data available (UAW-Ford database), to efficiently identify relationships between hundreds of variables, and on the selection

recommendations provided by the data analysis software package IBM SPSS Modeler v18.0. Since ML algorithms learn over time, it is also proposed that learnings from this study be applied to other similar epidemiological databases as shown in *Figure 31* with the assumption that accuracy of the selected algorithm will improve with the addition of more data.

Future researchers analyzing similar epidemiological databases are recommended to fully understand the capability and feasibility of a ML algorithm before selecting it to build predictive models.

Findings from all three studies have direct application in the automotive industry and will be disseminated through peer-reviewed publications, and professional organizations.

5.3 Strength & Limitations

Although this study contributes to the existing literature on pain and discomfort in the automotive sector, several limitations must be mentioned. The cross-sectional design of the original study was the most important limitation, which restricts definitive conclusions and precludes us from drawing causal relationships among the dependent and independent variables.

Secondly, the use of a dichotomous case-definition can be viewed as limitation, as an argument can be made on the use of cut-points. However, the instrument used to collect information was self-reported, data on '*Intensity of pain and discomfort in the last year'* was collected using a 0-100 VAS and the minimum score across all major

anatomical groups was over 27. Which is why a strategic decision was made to use the current case-definition.

Lastly, the present study successfully accomplishes its primary purpose of creating a holistic picture of the involvement of multiple risk factors across all major anatomical sites while adjusting for confounding factors such as sex, age and the difficulty of the job.

5.4 Conclusion

Musculoskeletal disorders in an automotive industry are associated with a combination multiple risk factors and a holistic approach should be taken in determining the exact cause of an injury and when developing preventive interventions.

Pain and discomfort experienced by an employee working in an automotive manufacturing environment is rarely localized and there exists a high prevalence of multi-site pain and discomfort. Interventions designed to treat localized pain and discomfort in an employee should take into consideration the high probability of the pain and discomfort manifesting at other anatomical sites as well.

Employees experiencing pain and discomfort in an automotive industry fall on a spectrum of disability and seldom into distinct categories of “in pain” or “completely pain free”. Musculoskeletal injuries are caused due to multiple risk factors over a long period of time and subsequently take a long time to heal. An effort needs to be made in understanding how severe one employee’s concerns is over other (who is more hurt/more disabled?) and a scale such as the proposed CSS can help in prioritizing resources to treat and manage employees with a higher disability score.

5.5 Future Scope

1. The results from the current study should be checked for repeatability and validity with a potential prospective study or a prospective database.
2. The results from the current study should be verified for repeatability using other case definitions such as FTOV, and other definitive medical diagnoses.
3. Use of the 'Medical Data' was out of the scope of the current study but it contains important information on subjects' reporting of pain on palpation and range of motion across all anatomical sites. These criteria's need to be further studied as dependent variables.
4. Role of sleep and rest on injury recovery cannot be ignored and data on sleep and rest needs to be collected in the event a similar study is repeated.
5. Individuals experiencing any pain or discomfort are likely to fall on a spectrum of disability rather than simply categorized as hurt or unhurt. The concept of a "Continuous Severity Scale" needs to be further explored.
6. Use of machine learning as a tool to build even more predictive models needs to be further explored by "feeding in" multiple epidemiological databases.

Appendices

Appendix [1]

Auburn University Institutional Review Board (IRB) Approval

Auburn University Human Research Protection Program

EXEMPTION REVIEW APPLICATION

For information or help completing this form, contact: **THE OFFICE OF RESEARCH COMPLIANCE,**
Location: 115 Ramsay Hall **Phone:** 334-844-5966 **Email:** IRBAdmin@auburn.edu

Submit completed application and supporting material as one attachment to IRBsubmit@auburn.edu.

1. PROJECT IDENTIFICATION

Date 10/01/2019

a. Project Title Creating a database to analyze the effects of personal characteristics on the risk of developing an injury or a musculoskeletal disorder.

b. Principal Investigator Anjaneya Bandekar Degree(s) Ph.D. Industrial & Systems Engineering
Rank/Title Graduate Research Assistant Department/School Industrial & Systems Engineering
Phone Number (334)559-1279 AU Email aab0066@auburn.edu

Faculty Principal Investigator (required if PI is a student) Dr. Richard Sesek
Title Tim Cook Associate Professor Department/School Industrial & Systems Engineering
Phone Number (334)728-1438 AU Email sesek@auburn.edu

Dept Head Dr. John Evans Department/School Industrial & Systems Engineering
Phone Number (334)844-1418 AU Email evansjl@auburn.edu

c. Project Personnel (other PI) – Identify all individuals who will be involved with the conduct of the research and include their role on the project. Role may include design, recruitment, consent process, data collection, data analysis, and reporting. Attach a table if needed for additional personnel.

Personnel Name Degree (s)
Rank/Title Department/School
Role
AU affiliated? ☐ YES ☐ NO If no, name of home institution
Plan for IRB approval for non-AU affiliated personnel?

Personnel Name Degree (s)
Rank/Title Department/School
Role
AU affiliated? ☐ YES ☐ NO If no, name of home institution
Plan for IRB approval for non-AU affiliated personnel?

Personnel Name Degree (s)
Rank/Title Department/School
Role
AU affiliated? ☐ YES ☐ NO If no, name of home institution
Plan for IRB approval for non-AU affiliated personnel?

d. Training – Have all Key Personnel completed CITI human subjects training (including elective modules related to this research) within the last 3 years? YES ■ NO ☐

The Auburn University Institutional Review Board has approved this Document for use from
10/04/2019 to ----------
Protocol # 19-454 EX 1910

e. Funding source – Is this project funded bythe investigator(s)? ☐ YES ■ NO
Is this project funded by AU? ☐ YES ■ NO If YES, identify source _____
Is this project funded by an external sponsor? ☐ YES ■ No If YES, provide the name of the sponsor, type of sponsor (governmental, non-profit, corporate, other), and an identification number for theaward.
Name_____Type_____Grant #_____

f. List other IRBs associated with this research and submit a copy of their approval and/orprotocol.

Insert OG IRB

2. Mark the category or categories below that describe the proposedresearch:

☐ 1. Research conducted in established or commonly accepted educational settings, involving normal educational practices. The research is not likely to adversely impact students' opportunity to learn or assessment of educators providing instruction. 104(d)(1)

☐ 2. Research only includes interactions involving educational tests, surveys, interviews, public observation if at least ONE of the following criteria. (The research includes data collection only; may include visual or auditory recording; may NOT include intervention and only includes interactions). **Mark the applicable sub-category below (i, ii, or iii).** 104(d)(2)

☐ (i) Recorded information cannot readily identify the participant (directlyorindirectly/linked); OR
- surveys and interviews: no children;
- educational tests or observation of public behavior: can only include children when investigators do not participate in activities being observed.

☐ (ii) Any disclosures of responses outside would not reasonably place participant at risk; OR

☐ (iii) Information is recorded with identifiers or code linked to identifiers and IRB conducts limited review; no children. **Requires limited review by theIRB.***

☐ 3. Research involving Benign Behavioral Interventions (BBI)** through verbal, written responses (including data entry or audiovisual recording) from adult subjects who prospectively agree and ONE of the following criteria is met. (This research does not include children and does not include medical interventions. Research cannot have deception unless the participant prospectively agrees that they will be unaware of or misled regarding the nature and purpose of the research)
Mark the applicable sub-category below (A, B, or C). 104(d)(3)(i)

☐ **(A)** Recorded information cannot readily identify the subject (directly or indirectly/linked); OR

☐ **(B)** Any disclosure of responses outside of the research would not reasonably placesubject at risk; OR

☐ **(C)** Information is recorded with identifiers and cannot have deception unless participant prospectively agrees. **Requires limited review by theIRB.***

■ 4. Secondary research for which consent is not required: use of identifiable information or identifiable bio-specimen that have been or will be collected for some other 'primary' or 'initial' activity, if one of the following criteria is met. Allows retrospective and prospective secondary use. **Mark the applicable sub-category below (I, ii, iii, or iv).** 104(d)(4)

☐ (i) Biospecimens or information are publically available;

☐ (ii) Information recorded so subject cannot readily be identified, directlyorindirectly/linked; investigator does not contact subjects and will not re-identify thesubjects;OR

☐ (iii) Collection and analysis involving investigators use of identifiable health information when use is regulated by HIPAA "health care operations" or "research or "public health activities and purposes" (does not include biospecimens (only PHI and requires federal guidance on how to apply); OR

☐ (iv) Research information collected by or on behalf of federal government usinggovernment generated or collected information obtained for non-researchactivities.

☐ 5. Research and demonstration projects which are supported by a federal agency/department AND designed to study and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs;(iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs. (must be posted on a federal web site). 104(d)(5) (must be posted on a federal web site)

☐ 6. Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture. The research does not involve prisoners as participants. 104(d)(6)

New exemption categories 7 and 8: Both categories 7 and 8 require Broad Consent. (Broad consent is a new type of informed consent provided under the Revised Common Rule pertaining to storage, maintenance, and secondary research with identifiable private information or identifiable biospecimens. Secondary research refers to research use of materials that are collected for either research studies distinct from the current secondary research proposal, or for materials that are collected for non-research purposes, such as materials that are left over from routine clinical diagnosis or treatments. Broad consent does not apply to research that collects information or biospecimens from individuals through direct interaction or intervention specifically for the purpose of the research.) **The Auburn University IRB has determined that as currently interpreted, Broad Consent is not feasible at Auburn and these 2 categories WILL NOT BE IMPLEMENTED at this time.**

***Limited IRB review* – the IRB Chairs or designated IRB reviewer reviews the protocol to ensure adequate provisions are in place to protect privacy and confidentiality.**

****Category 3 – Benign Behavioral Interventions (BBI)* must be brief in duration, painless/harmless, not physically invasive, not likely to have a significant adverse lasting impact on participants, and it is unlikely participants will find the interventions offensive or embarrassing.**

3. PROJECT SUMMARY

a. Does the study target any special populations? (Mark applicable)

Minors (under 19)	☐ YES ■ NO
Pregnant women, fetuses, or any products of conception	☐ YES ■ NO
Prisoners or wards (unless incidental, not allowed for Exempt research)	☐ YES ■ NO
Temporarily or permanently impaired	☐ YES ■ NO

b. Does the research pose more than minimal risk to participants? ☐ YES ■ NO

Minimal risk means that the probability and magnitude of harm or discomfort anticipated in the research are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or test. 42 CFR 46.102(i)

c. Does the study involve any of the following?

Procedures subject to FDA regulations (drugs, devices, etc.)	☐ YES ■ NO
Use of school records of identifiable students or information from instructors about specific students.	☐ YES ■ NO
Protected health or medical information when there is a direct or Indirect link which could identify the participant.	☐ YES ■ NO
Collection of sensitive aspects of the participant's own behavior, such as illegal conduct, drug use, sexual behavior or alcohol use.	☐ YES ■ NO
Deception of participants	☐ YES ■ NO

4. Briefly describe the proposed research, including purpose, participant population, recruitment process, consent process, research procedures and methodology.

This research includes medical and personal data collected across six automotive manufacturing facilities in 1998 which includes (n=1022) subjects, male and female with ages ranging from 20.26 years to 70.86 years, working 750 jobs.

My advisor, Dr. Richard Sesek collected this data for his dissertation, which was funded by UAW-Ford Joint Committee for Health and Safety.

RECRUITMENT PROCESS: -N/A-
Anonymized data from Dr. Sesek's database will be used.

CONSENT PROCESS: -N/A-
All study participants were consented in the original study, which included video-taping them performing their jobs.

RESERACH PROCEDURES & METHODOLOGY:

5. Waivers

Check any waivers that apply and describe how the project meets the criteria for the waiver. Provide the rationale for the waiver request.

- ■ **Waiver of Consent (Including existing de-identified data)**
- ■ **Waiver of Documentation of Consent (Use of Information Letter)**
- ■ **Waiver of Parental Permission (for college students)**

All retrospective information will be de-identified.

6. Describe how participants/data/specimens will be selected. If applicable, include gender, race, and ethnicity of the participant population.

The data was collected for all employees across six automotive manufacturing facilities in 1998 who willingly agreed to participate in the research study. No one was excluded on the basis of their gender, race, ethnicity or age.

Three types of data were collected:

1. VIDEO

The subjects were videotaped while they performed their respective job.

2. INTERVIEW DATA

The participants were interviewed by competent Occupational Health Nurses and Occupational Therapists about their pain and discomfort levels across eight body parts (Head/Neck, Shoulder, Elbow, Hand/Wrist, Low Back, Hips, Knee and Ankle/Feet)

3. MEDICAL ASSESSMENT DATA

Professional medical doctors conducted a medical assessment of all the participants. These assessments include; specific diagnostic tests and range of motion assessment across eight body parts (Head/Neck, Shoulder, Elbow, Hand/Wrist, Low Back, Hips, Knee and Ankle/Feet)

7. Does the research involve deception? ☐ YES ☒ NO If YES, please provide the rationale for deception and describe the debriefing process.

8. **Describe why none of the research procedures would cause a participant either physical or psychological discomfort or be perceived as discomfort above and beyond what the personwould experience in dailylife.**

This research is a retrospective analysis of data collected in 1998 and will not involve any interaction or communication with human subjects.

All available data has been anonymized in aggregate form.

9. **Describe the provisions to maintain confidentiality of data, including collection, transmission, and storage.**

Interview data and the Medical Assessment data from the study exists in a computer spreadsheet and in physical files.

Data that is in the spreadsheet consists of personal characteristics such as height, weight, gender and BMI but, is stripped of all personal identifiers. Subjects in this spreadsheet only exist in the form Subject ID's (four digit random number) and Job ID's (four digit random number).

Physical files containing data of all participants are securely stored in a locked cabinet room (Shelby 3323B). The access (key) to this room is only available to Dr. Richard Sesek and other senior faculty members of the Occupational Safety and Ergonomics Program within the department of Industrial & Systems Engineering.

Video of all participants exist in several VHS tapes without any personal identifiers. Video of each participant is named according to their Subject ID's (four digit random number). All subjects depicted in images and videos provided informed consent regarding use of their image and videos.

10. Describe the provisions included in the research to project the privacy interests ofparticipants (e.g., others willnot overhear conversations with potential participants, individuals will not be publicly identified or embarrassed).

-N/A-

All the data was collected over twenty years ago and is maintained in an anonymized aggregated form.

11. Will the research involve interacting (communication or direct involvement) with participants?
☐ YES ☒ NO If YES, describe the consent process and information to be presented tosubjects. This includes identifying that the activities involve research; that participation is voluntary; describing the procedures to be performed; and the PI name and contact information.

12. Additional Information and/or attachments.

In the space below, provide any additional information you believe may help the IRB review of the proposed research. If attachments are included, list the attachments below. Attachments may include recruitment materials, consent documents, site permissions, IRB approvals from other institutions, etc.

I have attached a copy of the agreement from Dr. Richard Sesek, which states that he is willingly sharing this data with me (Anjaneya Bandekar).

Principal Investigator's Signature _____ **Date** 10/01/2019

If PI is a student,
Faculty PrincipalInvestigator's Signature _____ **Date** 10/01/2019

Department Head's Signature _____ **Date** 10/01/2019

AUBURN
UNIVERSITY

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AUBURN, AL 36849-5346

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334-844-4340

FAX:
334-844-1381

www.auburn.edu

SAMUEL GINN COLLEGE OF ENGINEERING
INDUSTRIAL AND SYSTEMS ENGINEERING

October 2, 2019

Data Sharing and Usage Agreement

The purpose of this document is to establish a data sharing and usage agreement between the data provider, Richard F. Sesek and the data recipient, Anjaneya A. Bandekar.

The data provider collected medical and personal interview data across six Ford manufacturing facilities in 1998 as a part of his dissertation which was funded by the UAW-Ford Joint Committee for Health and Safety.

The data provider permits the share and usage of this data with the data recipient in the capacity of the recipient's doctoral advisor. This data to be shared, contains no personal identifiers and the confidentiality of all the subjects/participants from the original study is well preserved.

The purpose of this data share is to allow the recipient to perform a retrospective analysis to test a variety of models, including existing ergonomic assessment tools, to explore novel combination of health and injury outcomes.
The confidentiality of the data itself will be protected as follows:

1. The data recipient will not release data to a third party without prior approval from the data provider.
2. The data recipient will not share, publish, or otherwise release any findings or conclusions derived from the analysis of the data provided from the data provider without prior approval of the data provider.

Below are the signatures of the data provider and the data recipient.

DATA PROVIDER:

Richard F. Sesek, Ph.D.
Tim Cook Associate Professor, Industrial and Systems Engineering

DATA RECIPIENT:

Anjaneya A. Bandekar
Graduate Research Assistant, Industrial and Systems Engineering

CITI PROGRAM

Completion Date 29-Sep-2019
Expiration Date 28-Sep-2023
Record ID 33549601

This is to certify that:

Anjaneya Bandekar

Has completed the following CITI Program course:

CITI Conflicts of Interest (Curriculum Group)
Conflicts of Interest (Course Learner Group)
1 - Stage 1 (Stage)

Under requirements set by:

Auburn University

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?wc0469f37-1d75-4f3a-a4e3-2256205f0c34-33549601

CITI PROGRAM

Completion Date 29-Sep-2019
Expiration Date 28-Sep-2022
Record ID 31783246

This is to certify that:

Anjaneya Bandekar

Has completed the following CITI Program course:

IRB #1 Health Science Emphasis - AU Personnel - Basic/Refresher (Curriculum Group)
IRB #1 Health Science Emphasis - AU Personnel (Course Learner Group)
1 - Basic Course (Stage)

Under requirements set by:

Auburn University

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w86eecbce-0a75-4bd1-bf84-21736040dc82-31783246

CITI PROGRAM

Completion Date 29-Sep-2019
Expiration Date 28-Sep-2022
Record ID 27663453

This is to certify that:

Anjaneya Bandekar

Has completed the following CITI Program course:

IRB #1 Health Science Emphasis - Non-AU Personnel - Basic/Refresher (Curriculum Group)
IRB #1 Health Science Emphasis - Non-AU Personnel (Course Learner Group)
1 - Basic Course (Stage)

Under requirements set by:

Auburn University

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?wae37784c-d194-4e21-91bf-581fd15dc0a1-27663453

CITI PROGRAM

Completion Date 29-Sep-2019
Expiration Date 28-Sep-2022
Record ID 31767338

This is to certify that:

Anjaneya Bandekar

Has completed the following CITI Program course:

IRB Additional Modules (Curriculum Group)
Records-Based Research (Course Learner Group)
1 - Basic Course (Stage)

Under requirements set by:

Auburn University

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w43956157-0bfc-4654-912d-8d67e6643874-31767338

CITI PROGRAM

Completion Date 28-Jun-2018
Expiration Date 27-Jun-2021
Record ID 27663452

This is to certify that:

Anjaneya Bandekar

Has completed the following CITI Program course:

IRB Additional Modules	(Curriculum Group)
Workers as Research Subjects - A Vulnerable Population	(Course Learner Group)
1 - Basic Course	(Stage)

Under requirements set by:

Auburn University

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w5f4849df-5046-4844-aed4-59cf25aa8135-27663452

CITI PROGRAM

Completion Date 14-May-2019
Expiration Date 13-May-2023
Record ID 25536845

This is to certify that:

Richard Sesek

Has completed the following CITI Program course:

CITI Conflicts of Interest (Curriculum Group)
Conflicts of Interest (Course Learner Group)
2 - Refresher (Stage)

Under requirements set by:

Auburn University

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w2d7a68b2-c7f7-487f-95d9-767c2a51132f-25536845


CITI PROGRAM

Completion Date 25-May-2017
Expiration Date 24-May-2020
Record ID 21674781

This is to certify that:

Richard Sesek

Has completed the following CITI Program course:

IRB #1 Health Science Emphasis - AU Personnel - Basic/Refresher (Curriculum Group)
IRB #1 Health Science Emphasis - AU Personnel (Course Learner Group)
1 - Basic Course (Stage)

Under requirements set by:

Auburn University

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w50371e07-03c4-4c90-83e7-aefcfd52956a-21674781


CITI PROGRAM
Completion Date 25-May-2017
Expiration Date 24-May-2020
Record ID 21674777
This is to certify that:
Richard Sesek
Has completed the following CITI Program course:
IRB Additional Modules (Curriculum Group)
HIPAA and Human Subjects Research (Course Learner Group)
1 - Basic Course (Stage)
CITI
Collaborative Institutional Training Initiative
Under requirements set by:
Auburn University
Verify at www.citiprogram.org/verify/?w5f6deb73-1f9e-4d32-8569-67a2c187c52a-21674777

Appendix [2]

Structured Interview Form

Interview Questionnaire Form

PERSONAL DATA SHEET: UAW-FORD STUDY

Date: mm/dd/yy

Name: _____ Social Security: _____

Home Address: _____

City: _____ State: _____ Zip: _____

Home Phone Number: _____

INTERVIEW: UAW-FORD STUDY

1 Date: mm/dd/yy 2. Interviewer: _____

3. D.O.B.: mm/dd/yy 4.-5. Ht. ft __ in __ 6. Wt.: lbs. ____

7. Gender: Male ☐ Female ☐

8. Are you right handed? ☐ Left-handed ☐ Ambidextrous ☐

9. DROT/DEPT #: _____ 10. PROCESS/JOB #: _____

11, Job Title/Name: _____

12. Shift worked? Day shift ☐ Swing shift ☐

13. Usual number of hours worked/week? _____

14. Time on **CURRENT JOB(S)**? years: ___ months: ___ weeks: ___ days: ___

15. On your **CURRENT JOB(S)** how long has it been since your last musculoskeletal injury? years: ___ months: ___ weeks: ___ days: ___

16. If you are currently on shift how many hours have you worked today: _____

17. Hay you done other jobs in the **LAST YEAR** for more than **2 WEEKS** at a time? No ☐ Yes ☐

If yes, please provide the information requested below. If more than 2 jobs in the **LAST YEAR**, include those on which you worked the longest?

1. Plant #: _____ Dept #: _____
Job Title/Name?: _____
Time on that job during the **LAST YEAR**? months: _____ weeks: _____

2. Plant #: _____ Dept #: _____
Job Title/Name?: _____
Time on that job during the **LAST YEAR**? months: _____ weeks: _____

18. Have you ever been told by a health care provider that you had any of the following health problems?

1) Diabetes: No ☐ Yes ☐ 2) Thyroid problems: No ☐ Yes☐
3) Rheumatoid arthritis: No ☐ Yes ☐ 4) Osteo arthritis: No ☐ Yes☐
5) Hypertension: No ☐ Yes ☐ 6) Neurological disorders: No ☐ Yes☐

Female workers only

7) Are you pregnant now? No ☐ Yes ☐ NA ☐
8) Are you currently taking birth control pills? No ☐ Yes ☐ NA ☐
9) Have you had a hysterectomy/oophorectomy? No ☐ Yes ☐ NA ☐

19. Are you a current smoker? ☐ Ex-smoker ☐ Never smoked? ☐

20. In what kinds of out of plant activities are you or have you been involved during the last year?

1. Outside job or business: _____ Hours/Times/Week: _____
_____ Hours/Times/Week: _____
_____ Hours/Times/Week: _____

Musculoskeletal risk factors? low ☐ med ☐ high ☐

2. Sports: _____ Hours/Times/Week: _____
_____ Hours/Times/Week: _____
_____ Hours/Times/Week: _____

Musculoskeletal risk factors? low ☐ med ☐ high ☐

3. Hobbies: _____ Hours/Times/Week: _____
_____ Hours/Times/Week: _____
_____ Hours/Times/Week: _____

Musculoskeletal risk factors? low ☐ med ☐ high ☐

4. Arts/Crafts: _____ Hours/Times/Week: _____
_____ Hours/Times/Week: _____
_____ Hours/Times/Week: _____

Musculoskeletal risk factors? low ☐ med ☐ high ☐

5. Others: _____ Hours/Times/Week: _____
_____ Hours/Times/Week: _____
_____ Hours/Times/Week: _____

Musculoskeletal risk factors? low ☐ med ☐ high ☐

21. Have you experienced musculoskeletal pain or discomfort during the **PAST YEAR**? no ☐ yes ☐

    If YES, carefully shade in areas of the drawing on the next page that have or do bother you the Most.

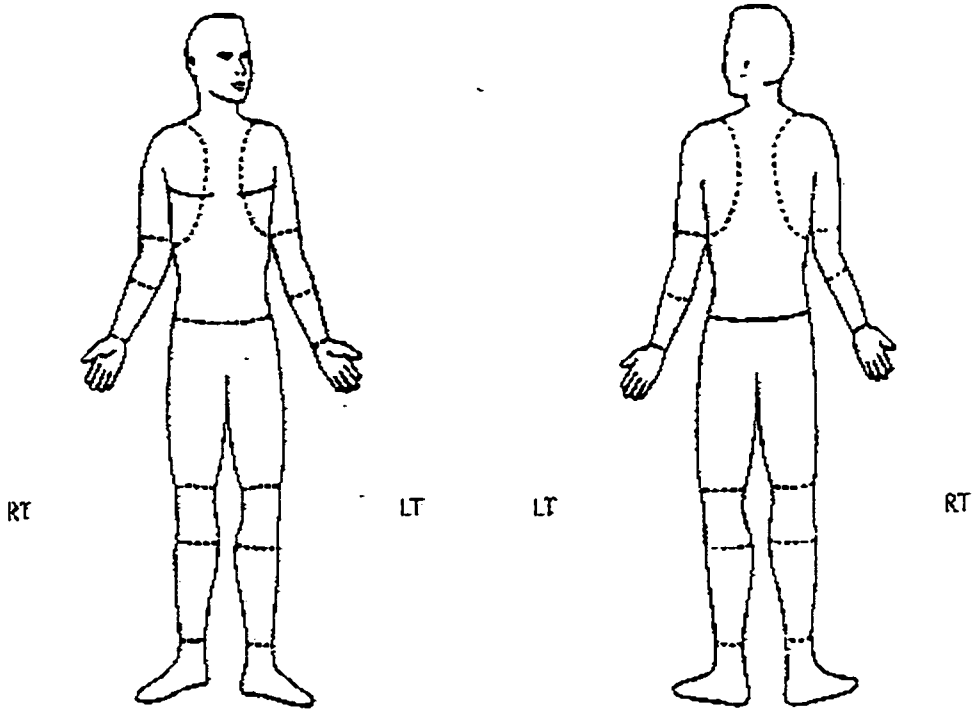
22. Separate sections are available for the following body sites. Please check sections to be completed.

Head/Neck ☐	Shoulder ☐	Elbow ☐	Hand/Wrist ☐	
Lower Back ☐	Hips ☐	Knees ☐	Ankles/Feet ☐	None ☐

Please complete a separate section for each body site in which the worker notes he/she has symptoms

BODY MAP

Carefully shade in areas of the drawing below that have or do bother you the **Most**.



FRONT **BACK**

HEAD/NECK

1. Have you experienced musculoskeletal pain or discomfort of your **head/neck** during the **PAST YEAR**? No ☐ Yes ☐

2. Which of the following word(s) best describe your musculoskeletal symptoms? (Check all that apply)

1) Aching ☐	2) Pain ☐	3) Weakness ☐
4) Burning ☐	5) Swelling ☐	6) Knots ☐
7) Cramping ☐	8) Spasms ☐	9) Nocturnal discomfort ☐
10) Loss of color ☐	11) Stiffness ☐	12) Numbness ☐
13) Tingling ☐	14) Other ☐	(Please explain) _____
15) None ☐		_____

3. Were you working on your **CURRENT JOB(S)** when these musculoskeletal symptoms started? Yes ☐ No ☐
If **NO**, since working on your **CURRENT JOB(S)** have the musculoskeletal symptoms: gotten worse ☐ remained the same ☐ improved ☐

4. How many **SEPARATE** episodes have you experienced in the **LAST YEAR**? ____ (If Continuous enter 365 for question #4 and > 3 mo. for question #5)

5. How long does the **TYPICAL** episode last? (Mark the appropriate box)
< 1 hr ☐ 1 hr ☐ 1 da ☐ 1 wk ☐ 1 mo ☐ 2 mo ☐ 3 mo ☐ > 3 mo ☐

6. Which **ONE** of the symptoms on the above list gives you the **MOST** pain/discomfort? Use symptom number from the above list: _____.

7. Have you experienced this symptom in the **LAST 7 DAYS**? No ☐ Yes ☐

8. Draw a line that intersects the horizontal line at the point that best describes the **INTENSITY** of this SYMPTOM **TODAY**.

None Unbearable

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

9. Draw a line that intersects the horizontal line at the point that best describes the **INTENSITY** of this SYMPTOM **WHEN IT IS THE WORST.**

None Unbearable

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

10. Have you received treatment for this symptom? No ☐ Yes ☐
If **NO**, Why not _____

If **Yes**, where did you receive treatment? (Mark all that apply)
Plant clinic? ☐ How many time in last year: _____
Outside of plant? ☐ How many time in last year: _____

11. How much **LOST WORK TIME** have you taken in the **LAST YEAR** due to this musculoskeletal symptom? # of days: _____

12. How many days were you on **RESTRICTED/LIGHT** duty in the **LAST YEAR** due to this musculoskeletal symptom. # of days: _____

13. Since working on your **CURRENT JOB(S)** how much **LOST WORK TIME** have you taken due to this musculoskeletal symptom. # of days: _____

14. Since working on your **CURRENT JOB(S)** how many days have you been on **RESTRICTED/LIGHT** duty due to this musculoskeletal symptom.
# of days: _____

15. **IF RELATED** to your **CURRENT JOB(S)** what do you think **CAUSED** the musculoskeletal symptoms of your **head/neck**? _____

16. Are there tasks related to your **CURRENT JOB(S)** that you think **AGGRAVATE** the musculoskeletal symptoms of you **head/neck**? _____

17. Are your **head/neck** symptoms related to a **PREVIOUS CONDITION OR INJURY**? No ☐ Yes☐ If yes, please explain _____

SHOULDER(S)

1. Have you experienced musculoskeletal pain or discomfort of your **shoulder(s)** during the **PAST YEAR**? No ☐ If yes please specify: right ☐ left ☐ both ☐

2. Which of the following word(s) best describe your musculoskeletal symptoms? (Check all that apply)

1) Aching ☐	2) Pain ☐	3) Weakness ☐
4) Burning ☐	5) Swelling ☐	6) Knots ☐
7) Cramping ☐	8) Spasms ☐	9) Nocturnal discomfort ☐
10) Loss of color ☐	11) Stiffness ☐	12) Numbness ☐
13) Tingling ☐	14) Other ☐	(Please explain) _____
15) None ☐		_____

3. Were you working on your **CURRENT JOB(S)** when these musculoskeletal symptoms started? Yes ☐ No ☐
   If **NO**, since working on your **CURRENT JOB(S)** have the musculoskeletal symptoms: gotten worse ☐ remained the same ☐ improved ☐

4. How many **SEPARATE** episodes have you experienced in the **LAST YEAR**?
   ____ (If Continuous enter 365 for question #4 and > 3 mo. for question #5)

5. How long does the **TYPICAL** episode last? (Mark the appropriate box)
   < 1 hr ☐ 1 hr ☐ 1 da ☐ 1 wk ☐ 1 mo ☐ 2 mo ☐ 3 mo ☐ > 3 mo ☐

6. Which **ONE** of the symptoms on the above list gives you the **MOST** pain/discomfort? Use symptom number from the above list: _____.

7. Have you experienced this symptom in the **LAST 7 DAYS**? No ☐ Yes ☐

8. Draw a line that intersects the horizontal line at the point that best describes the **INTENSITY** of this SYMPTOM **TODAY**.

_____

None Unbearable

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

9. Draw a line that intersects the horizontal line at the point that best describes the **INTENSITY** of this SYMPTOM **WHEN IT IS THE WORST**.

None Unbearable

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

10. Have you received treatment for this symptom? No ☐ Yes ☐
If **NO**, Why not _____
_____

If **Yes**, where did you receive treatment? (Mark all that apply)
Plant clinic? ☐ How many time in last year: _____
Outside of plant? ☐ How many time in last year: _____

11. How much **LOST WORK TIME** have you taken in the **LAST YEAR** due to this musculoskeletal symptom? # of days: _____

12. How many days were you on **RESTRICTED/LIGHT** duty in the **LAST YEAR** due to this musculoskeletal symptom. # of days: _____

13. Since working on your **CURRENT JOB(S)** how much **LOST WORK TIME** have you taken due to this musculoskeletal symptom. # of days: _____

14. Since working on your **CURRENT JOB(S)** how many days have you been on **RESTRICTED/LIGHT** duty due to this musculoskeletal symptom.
# of days: _____

15. **IF RELATED** to your **CURRENT JOB(S)** what do you think **CAUSED** the musculoskeletal symptoms of your **shoulder(s)**? _____

_____

16. Are there tasks related to your **CURRENT JOB(S)** that you think **AGGRAVATE** the musculoskeletal symptoms of you **shoulder(s)**? _____

_____

17. Are your **shoulder(s)** symptoms related to a **PREVIOUS CONDITION OR INJURY**? No ☐ Yes☐ If yes, please explain _____

_____

ELBOW(S)

1. Have you experienced musculoskeletal pain or discomfort of your **elbow(s)** during the **PAST YEAR**? No ☐ If yes please specify: right ☐ left ☐ both ☐

2. Which of the following word(s) best describe your musculoskeletal symptoms? (Check all that apply)

1) Aching ☐	2) Pain ☐	3) Weakness ☐
4) Burning ☐	5) Swelling ☐	6) Knots ☐
7) Cramping ☐	8) Spasms ☐	9) Nocturnal discomfort ☐
10) Loss of color ☐	11) Stiffness ☐	12) Numbness ☐
13) Tingling ☐	14) Other ☐ (Please explain) _____	
15) None ☐	_____	

3. Were you working on your **CURRENT JOB(S)** when these musculoskeletal symptoms started? Yes ☐ No ☐
If **NO**, since working on your **CURRENT JOB(S)** have the musculoskeletal symptoms: gotten worse ☐ remained the same ☐ improved ☐

4. How many **SEPARATE** episodes have you experienced in the **LAST YEAR**? ____ (If Continuous enter 365 for question #4 and > 3 mo. for question #5)

5. How long does the **TYPICAL** episode last? (Mark the appropriate box)
< 1 hr ☐ 1 hr ☐ 1 da ☐ 1 wk ☐ 1 mo ☐ 2 mo ☐ 3 mo ☐ > 3 mo ☐

6. Which **ONE** of the symptoms on the above list gives you the **MOST** pain/discomfort? Use symptom number from the above list: _____.

7. Have you experienced this symptom in the **LAST 7 DAYS**? No ☐ Yes ☐

8. Draw a line that intersects the horizontal line at the point that best describes the **INTENSITY** of this SYMPTOM **TODAY**.

None Unbearable

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

9. Draw a line that intersects the horizontal line at the point that best describes the **INTENSITY** of this SYMPTOM **WHEN IT IS THE WORST**.

None Unbearable

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

10. Have you received treatment for this symptom? No ☐ Yes ☐
If **NO**, Why not _____

If **Yes**, where did you receive treatment? (Mark all that apply)
Plant clinic? ☐ How many time in last year: _____
Outside of plant? ☐ How many time in last year: _____

11. How much **LOST WORK TIME** have you taken in the **LAST YEAR** due to this musculoskeletal symptom? # of days: _____

12. How many days were you on **RESTRICTED/LIGHT** duty in the **LAST YEAR** due to this musculoskeletal symptom. # of days: _____

13. Since working on your **CURRENT JOB(S)** how much **LOST WORK TIME** have you taken due to this musculoskeletal symptom. # of days: _____

14. Since working on your **CURRENT JOB(S)** how many days have you been on **RESTRICTED/LIGHT** duty due to this musculoskeletal symptom.
# of days: _____

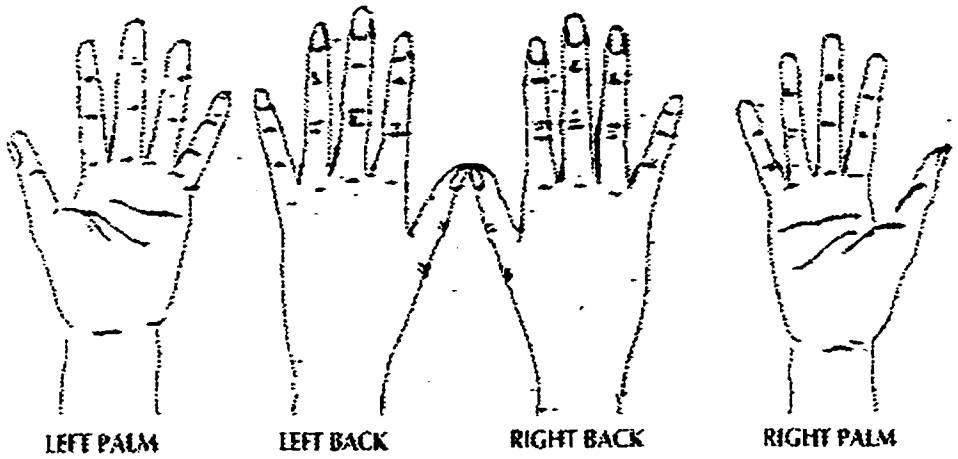
15. **IF RELATED** to your **CURRENT JOB(S)** what do you think **CAUSED** the musculoskeletal symptoms of your **elbow(s)**? _____

16. Are there tasks related to your **CURRENT JOB(S)** that you think **AGGRAVATE** the musculoskeletal symptoms of you **elbow(s)**? _____

17. Are your **elbow(s)** symptoms related to a **PREVIOUS CONDITION OR INJURY**? No ☐ Yes☐ If yes, please explain _____

HAND(S)/WRIST(S)

1. Have you experienced musculoskeletal pain or discomfort of your **hand(s)/wrist(s)** during the **PAST YEAR**? No ☐
   If yes please specify: right ☐ left ☐ both ☐
   If **YES**, carefully shade in areas of the drawing that have or do bother you the **Most**.



2. Which of the following word(s) best describe your musculoskeletal symptoms? (Check all that apply)

1) Aching ☐	2) Pain ☐	3) Weakness ☐
4) Burning ☐	5) Swelling ☐	6) Knots ☐
7) Cramping ☐	8) Spasms ☐	9) Nocturnal discomfort ☐
10) Loss of color ☐	11) Stiffness ☐	12) Numbness ☐
13) Tingling ☐	14) Other ☐	(Please explain) _____
15) None ☐		_____

3. Were you working on your **CURRENT JOB(S)** when these musculoskeletal symptoms started? Yes ☐ No ☐
   If **NO**, since working on your **CURRENT JOB(S)** have the musculoskeletal symptoms: gotten worse ☐ remained the same ☐ improved ☐

4. How many **SEPARATE** episodes have you experienced in the **LAST YEAR**?
   _____ (If Continuous enter 365 for question #4 and > 3 mo. for question #5)

5. How long does the **TYPICAL** episode last? (Mark the appropriate box)
   < 1 hr ☐ 1 hr ☐ 1 da ☐ 1 wk ☐ 1 mo ☐ 2 mo ☐ 3 mo ☐ > 3 mo ☐

6. Which **ONE** of the symptoms on the above list gives you the **MOST** pain/discomfort? Use symptom number from the above list: _____.

7. Have you experienced this symptom in the **LAST 7 DAYS**? No ☐ Yes ☐

8. Draw a line that intersects the horizontal line at the point that best describes the **INTENSITY** of this SYMPTOM **TODAY**.

None Unbearable

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

9. Draw a line that intersects the horizontal line at the point that best describes the **INTENSITY** of this SYMPTOM **WHEN IT IS THE WORST**.

None Unbearable

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

10. Have you received treatment for this symptom? No ☐ Yes ☐
If **NO**, Why not _____
_____

If **Yes**, where did you receive treatment? (Mark all that apply)
Plant clinic? ☐ How many time in last year: _____
Outside of plant? ☐ How many time in last year: _____

11. How much **LOST WORK TIME** have you taken in the **LAST YEAR** due to this musculoskeletal symptom? # of days: _____

12. How many days were you on **RESTRICTED/LIGHT** duty in the **LAST YEAR** due to this musculoskeletal symptom. # of days: _____

13. Since working on your **CURRENT JOB(S)** how much **LOST WORK TIME** have you taken due to this musculoskeletal symptom. # of days: _____

14. Since working on your **CURRENT JOB(S)** how many days have you been on **RESTRICTED/LIGHT** duty due to this musculoskeletal symptom.
# of days: _____

15. **IF RELATED** to your **CURRENT JOB(S)** what do you think **CAUSED** the musculoskeletal symptoms of your **hand(s)/wrist(s)**? _____

_____

16. Are there tasks related to your **CURRENT JOB(S)** that you think **AGGRAVATE** the musculoskeletal symptoms of you **hand(s)/wrist(s)**? ___

_____

17. Are your **hand(s)/wrist(s)** symptoms related to a **PREVIOUS CONDITION OR INJURY**? No □ Yes□ If yes, please explain _____

_____

LOWER BACK

1. Have you experienced musculoskeletal pain or discomfort of your **Lower Back** during the **PAST YEAR**? No ☐ Yes ☐

2. Which of the following word(s) best describe your musculoskeletal symptoms? (Check all that apply)

1) Aching ☐	2) Pain ☐	3) Weakness ☐
4) Burning ☐	5) Swelling ☐	6) Knots ☐
7) Cramping ☐	8) Spasms ☐	9) Nocturnal discomfort ☐
10) Loss of color ☐	11) Stiffness ☐	12) Numbness ☐
13) Tingling ☐	14) Other ☐	(Please explain) _____
15) None ☐		_____

3. Were you working on your **CURRENT JOB(S)** when these musculoskeletal symptoms started? Yes ☐ No ☐
   If **NO**, since working on your **CURRENT JOB(S)** have the musculoskeletal symptoms: gotten worse ☐ remained the same ☐ improved ☐

4. How many **SEPARATE** episodes have you experienced in the **LAST YEAR**?
   ____ (If Continuous enter 365 for question #4 and > 3 mo. for question #5)

5. How long does the **TYPICAL** episode last? (Mark the appropriate box)
   < 1 hr ☐ 1 hr ☐ 1 da ☐ 1 wk ☐ 1 mo ☐ 2 mo ☐ 3 mo ☐ > 3 mo ☐

6. Which **ONE** of the symptoms on the above list gives you the **MOST** pain/discomfort? Use symptom number from the above list: _____.

7. Have you experienced this symptom in the **LAST 7 DAYS**? No ☐ Yes ☐

8. Draw a line that intersects the horizontal line at the point that best describes the **INTENSITY** of this SYMPTOM **TODAY**.

None Unbearable

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

9. Draw a line that intersects the horizontal line at the point that best describes the **INTENSITY** of this SYMPTOM **WHEN IT IS THE WORST.**

None Unbearable

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

10. Have you received treatment for this symptom? No □ Yes □
If **NO**, Why not _____

If **Yes**, where did you receive treatment? (Mark all that apply)
Plant clinic? □ How many time in last year: _____
Outside of plant? □ How many time in last year: _____

11. How much **LOST WORK TIME** have you taken in the **LAST YEAR** due to this musculoskeletal symptom? # of days: _____

12. How many days were you on **RESTRICTED/LIGHT** duty in the **LAST YEAR** due to this musculoskeletal symptom. # of days: _____

13. Since working on your **CURRENT JOB(S)** how much **LOST WORK TIME** have you taken due to this musculoskeletal symptom. # of days: _____

14. Since working on your **CURRENT JOB(S)** how many days have you been on **RESTRICTED/LIGHT** duty due to this musculoskeletal symptom.
# of days: _____

15. **IF RELATED** to your **CURRENT JOB(S)** what do you think **CAUSED** the musculoskeletal symptoms of your **lower back**? _____

16. Are there tasks related to your **CURRENT JOB(S)** that you think **AGGRAVATE** the musculoskeletal symptoms of you **lower back**? _____

17. Are your **lower back** symptoms related to a **PREVIOUS CONDITION OR INJURY**? No □ Yes□ If yes, please explain _____

HIP(S)

1. Have you experienced musculoskeletal pain or discomfort of your **hip(s)** during the **PAST YEAR**? No ☐ If yes please specify: right ☐ left ☐ both ☐

2. Which of the following word(s) best describe your musculoskeletal symptoms? (Check all that apply)

1) Aching ☐	2) Pain ☐	3) Weakness ☐
4) Burning ☐	5) Swelling ☐	6) Knots ☐
7) Cramping ☐	8) Spasms ☐	9) Nocturnal discomfort ☐
10) Loss of color ☐	11) Stiffness ☐	12) Numbness ☐
13) Tingling ☐	14) Other ☐	(Please explain) _____
15) None ☐		_____

3. Were you working on your **CURRENT JOB(S)** when these musculoskeletal symptoms started? Yes ☐ No ☐
   If **NO**, since working on your **CURRENT JOB(S)** have the musculoskeletal symptoms: gotten worse ☐ remained the same ☐ improved ☐

4. How many **SEPARATE** episodes have you experienced in the **LAST YEAR**? ____ (If Continuous enter 365 for question #4 and > 3 mo. for question #5)

5. How long does the **TYPICAL** episode last? (Mark the appropriate box)
   < 1 hr ☐ 1 hr ☐ 1 da ☐ 1 wk ☐ 1 mo ☐ 2 mo ☐ 3 mo ☐ > 3 mo ☐

6. Which **ONE** of the symptoms on the above list gives you the **MOST** pain/discomfort? Use symptom number from the above list: _____.

7. Have you experienced this symptom in the **LAST 7 DAYS**? No ☐ Yes ☐

8. Draw a line that intersects the horizontal line at the point that best describes the **INTENSITY** of this SYMPTOM **TODAY**.

   None ——————————————————— Unbearable

   [note: 10 cm scale appeared here in the actual form]

   Measured value: _____

9. Draw a line that intersects the horizontal line at the point that best describes the **INTENSITY** of this SYMPTOM **WHEN IT IS THE WORST**.

None Unbearable

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

10. Have you received treatment for this symptom? No □ Yes □
If **NO**, Why not _____

If **Yes**, where did you receive treatment? (Mark all that apply)
Plant clinic? □ How many time in last year: _____
Outside of plant? □ How many time in last year: _____

11. How much **LOST WORK TIME** have you taken in the **LAST YEAR** due to this musculoskeletal symptom? # of days: _____

12. How many days were you on **RESTRICTED/LIGHT** duty in the **LAST YEAR** due to this musculoskeletal symptom. # of days: _____

13. Since working on your **CURRENT JOB(S)** how much **LOST WORK TIME** have you taken due to this musculoskeletal symptom. # of days: _____

14. Since working on your **CURRENT JOB(S)** how many days have you been on **RESTRICTED/LIGHT** duty due to this musculoskeletal symptom.
# of days: _____

15. **IF RELATED** to your **CURRENT JOB(S)** what do you think **CAUSED** the musculoskeletal symptoms of your **hip(s)**? _____

16. Are there tasks related to your **CURRENT JOB(S)** that you think **AGGRAVATE** the musculoskeletal symptoms of you **hip(s)**? _____

17. Are your **hip(s)** symptoms related to a **PREVIOUS CONDITION OR INJURY**? No □ Yes□ If yes, please explain _____

KNEE(S)

1. Have you experienced musculoskeletal pain or discomfort of your **knee(s)** during the **PAST YEAR**? No ☐ If yes please specify: right ☐ left ☐ both ☐

2. Which of the following word(s) best describe your musculoskeletal symptoms? (Check all that apply)

1) Aching ☐	2) Pain ☐	3) Weakness ☐
4) Burning ☐	5) Swelling ☐	6) Knots ☐
7) Cramping ☐	8) Spasms ☐	9) Nocturnal discomfort ☐
10) Loss of color ☐	11) Stiffness ☐	12) Numbness ☐
13) Tingling ☐	14) Other ☐	(Please explain) _____
15) None ☐		_____

3. Were you working on your **CURRENT JOB(S)** when these musculoskeletal symptoms started? Yes ☐ No ☐
If **NO**, since working on your **CURRENT JOB(S)** have the musculoskeletal symptoms: gotten worse ☐ remained the same ☐ improved ☐

4. How many **SEPARATE** episodes have you experienced in the **LAST YEAR**?
____ (If Continuous enter 365 for question #4 and > 3 mo. for question #5)

5. How long does the **TYPICAL** episode last? (Mark the appropriate box)
< 1 hr ☐ 1 hr ☐ 1 da ☐ 1 wk ☐ 1 mo ☐ 2 mo ☐ 3 mo ☐ > 3 mo ☐

6. Which **ONE** of the symptoms on the above list gives you the **MOST** pain/discomfort? Use symptom number from the above list: _____.

7. Have you experienced this symptom in the **LAST 7 DAYS**? No ☐ Yes ☐

8. Draw a line that intersects the horizontal line at the point that best describes the **INTENSITY** of this SYMPTOM **TODAY**.

None Unbearable

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

9. Draw a line that intersects the horizontal line at the point that best describes the **INTENSITY** of this SYMPTOM **WHEN IT IS THE WORST**.

None Unbearable

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

10. Have you received treatment for this symptom? No ☐ Yes ☐
If **NO**, Why not _____

If **Yes**, where did you receive treatment? (Mark all that apply)
Plant clinic? ☐ How many time in last year: _____
Outside of plant? ☐ How many time in last year: _____

11. How much **LOST WORK TIME** have you taken in the **LAST YEAR** due to this musculoskeletal symptom? # of days: _____

12. How many days were you on **RESTRICTED/LIGHT** duty in the **LAST YEAR** due to this musculoskeletal symptom. # of days: _____

13. Since working on your **CURRENT JOB(S)** how much **LOST WORK TIME** have you taken due to this musculoskeletal symptom. # of days: _____

14. Since working on your **CURRENT JOB(S)** how many days have you been on **RESTRICTED/LIGHT** duty due to this musculoskeletal symptom.
# of days: _____

15. **IF RELATED** to your **CURRENT JOB(S)** what do you think **CAUSED** the musculoskeletal symptoms of your **knee(s)**? _____

16. Are there tasks related to your **CURRENT JOB(S)** that you think **AGGRAVATE** the musculoskeletal symptoms of you **knee(s)**? _____

17. Are your **knee(s)** symptoms related to a **PREVIOUS CONDITION OR INJURY**? No ☐ Yes☐ If yes, please explain _____

ANKLE(S)/FEET

1. Have you experienced musculoskeletal pain or discomfort of your **ankle(s)/feet** during the **PAST YEAR**? No ☐ If yes please specify: right ☐ left ☐ both ☐

2. Which of the following word(s) best describe your musculoskeletal symptoms? (Check all that apply)

1) Aching ☐	2) Pain ☐	3) Weakness ☐
4) Burning ☐	5) Swelling ☐	6) Knots ☐
7) Cramping ☐	8) Spasms ☐	9) Nocturnal discomfort ☐
10) Loss of color ☐	11) Stiffness ☐	12) Numbness ☐
13) Tingling ☐	14) Other ☐	(Please explain) _____
15) None ☐		_____

3. Were you working on your **CURRENT JOB(S)** when these musculoskeletal symptoms started? Yes ☐ No ☐
   If **NO**, since working on your **CURRENT JOB(S)** have the musculoskeletal symptoms: gotten worse ☐ remained the same ☐ improved ☐

4. How many **SEPARATE** episodes have you experienced in the **LAST YEAR**? _____ (If Continuous enter 365 for question #4 and > 3 mo. for question #5)

5. How long does the **TYPICAL** episode last? (Mark the appropriate box)
   < 1 hr ☐ 1 hr ☐ 1 da ☐ 1 wk ☐ 1 mo ☐ 2 mo ☐ 3 mo ☐ > 3 mo ☐

6. Which **ONE** of the symptoms on the above list gives you the **MOST** pain/discomfort? Use symptom number from the above list: _____.

7. Have you experienced this symptom in the **LAST 7 DAYS**? No ☐ Yes ☐

8. Draw a line that intersects the horizontal line at the point that best describes the **INTENSITY** of this SYMPTOM **TODAY**.

None Unbearable

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

9. Draw a line that intersects the horizontal line at the point that best describes the **INTENSITY** of this SYMPTOM **WHEN IT IS THE WORST**.

None Unbearable

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

10. Have you received treatment for this symptom? No □ Yes □
If **NO**, Why not _____
_____

If **Yes**, where did you receive treatment? (Mark all that apply)
Plant clinic? □ How many time in last year: _____
Outside of plant? □ How many time in last year: _____

11. How much **LOST WORK TIME** have you taken in the **LAST YEAR** due to this musculoskeletal symptom? # of days: _____

12. How many days were you on **RESTRICTED/LIGHT** duty in the **LAST YEAR** due to this musculoskeletal symptom. # of days: _____

13. Since working on your **CURRENT JOB(S)** how much **LOST WORK TIME** have you taken due to this musculoskeletal symptom. # of days: _____

14. Since working on your **CURRENT JOB(S)** how many days have you been on **RESTRICTED/LIGHT** duty due to this musculoskeletal symptom.
# of days: _____

15. **IF RELATED** to your **CURRENT JOB(S)** what do you think **CAUSED** the musculoskeletal symptoms of your **ankle(s)/feet**? _____

_____

16. Are there tasks related to your **CURRENT JOB(S)** that you think **AGGRAVATE** the musculoskeletal symptoms of you **ankle(s)/feet**? _____

_____

17. Are your **ankle(s)/feet** symptoms related to a **PREVIOUS CONDITION OR INJURY**? No □ Yes□ If yes, please explain _____

_____

WORKERS PERCEPTION OF PHYSICAL EFFORT/EXERTION RELATED TO DOING HIS/HER CURRENT JOB

Please complete all 5 questions below.

1. Draw a line that intersects the horizontal line at the point that best describes the amount of physical effort/exertion you place on your **HEAD/NECK** while doing your **CURRENT** job?

Low _____ High

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

2. Draw a line that intersects the horizontal line at the point that best describes the amount of physical effort/exertion you place on your **SHOULDERS** while doing your **CURRENT** job?

Low _____ High

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

3. Draw a line that intersects the horizontal line at the point that best describes the amount of physical effort/exertion you place on your **ELBOWS/HANDS/WRISTS** while doing your **CURRENT** job?

Low _____ High

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

4. Draw a line that intersects the horizontal line at the point that best describes the amount of physical effort/exertion you place on your **LOWER BACK** while doing your **CURRENT** job?

Low High

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

5. Draw a line that intersects the horizontal line at the point that best describes the amount of physical effort/exertion you place on your **HIPS/KNEES/ANKLES/FEET** while doing your **CURRENT** job?

Low High

[note: 10 cm scale appeared here in the actual form]

Measured value: _____

PERCEPTIONS ABOUT WORK AND HEALTH

For the questions below, please check the answer that comes closest to describing your situation. There are no right or wrong answers to these questions. We are interested in your ideas and your experiences.

1. My job requires that I learn new things.
   strongly disagree ☐ disagree ☐ agree ☐ strongly agree ☐

2. My job involves a lot of repetitive work.
   strongly disagree ☐ disagree ☐ agree ☐ strongly agree ☐

3. My job requires me to be creative.
   strongly disagree ☐ disagree ☐ agree ☐ strongly agree ☐

4. My job requires a high level of skill.
   strongly disagree ☐ disagree ☐ agree ☐ strongly agree ☐

5. On my job, I have very little freedom to decide how I do my work.
   strongly disagree ☐ disagree ☐ agree ☐ strongly agree ☐

6. I get to do a variety of different things on my job.
   strongly disagree ☐ disagree ☐ agree ☐ strongly agree ☐

7. I have a lot to say about what happens on my job.
   strongly disagree ☐ disagree ☐ agree ☐ strongly agree ☐

8. My job requires working very fast.
   strongly disagree ☐ disagree ☐ agree ☐ strongly agree ☐

9. My job requires working very hard.
   strongly disagree ☐ disagree ☐ agree ☐ strongly agree ☐

10. I am not asked to do an excessive amount of work.
    strongly disagree ☐ disagree ☐ agree ☐ strongly agree ☐

11. I have enough time to get the job done.
    strongly disagree ☐ disagree ☐ agree ☐ strongly agree ☐

12. My job is very hectic.
strongly disagree ☐ disagree ☐ agree ☐ strongly agree ☐

13. I can take a break when I want to.
strongly disagree ☐ disagree ☐ agree ☐ strongly agree ☐

14. My supervisor is willing to listen to my work related problems.
strongly disagree ☐ disagree ☐ agree ☐ strongly agree ☐

JOB SATISFACTION

1. All in all, how satisfied are you with your job?
not at all satisfied ☐ not too satisfied ☐ somewhat satisfied ☐ very satisfied ☐

2. How strongly would you recommend your job to someone else?
not at all recommend ☐ not too strongly recommend ☐ would recommend ☐ would strongly recommend ☐

3. If you were looking for a new job now, how likely is it that you would decide to take this job again?
not at all likely ☐ not too likely ☐ somewhat likely ☐ very likely ☐

Appendix [3]

Medical Interview Form

Medical Exam Form

UAW-FORD ERGONOMIC STUDY PHYSICAL EXAM

Name: _____

Study Site Trip 1 ☐ Trip 2 ☐ Trip 3 ☐ Trip 4 ☐ Trip 5 ☐

Day of Week Mon ☐ Tues ☐ Wed ☐ Thur ☐ Fri ☐

Examiner SF ☐ AS ☐ CK ☐ WA ☐ Other ☐

This Exam is Completely Normal Yes ☐ No ☐

Hand Dominance Right ☐ Left ☐

NECK

Is examination of the neck completely normal?

Yes ☐ (skip to right shoulder) No ☐ (continue below)

Range of motion in degrees

Flexion	0	5	10	15	20	25	30	35	40	45
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Extension	0	5	10	15	20	25	30	35	40	45
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Lateral Deviation

Right	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Left	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Right Rotation	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Left Rotation	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Tenderness to palpation along spinous processes

Yes ☐ (proceed) No ☐ (skip to next series)

Spinous processes and soft tissue

Tenderness	0	1	2	3	4	5	6	7	8	9	10
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Location	C2	C3	C4	C5	C6	C7	T1				
	☐	☐	☐	☐	☐	☐	☐				

Spasm of soft tissue

Yes ☐ (proceed) No ☐ (skip to next series)

Location

Right	C2	C3	C4	C5	C6	C7	T1	
		☐	☐	☐	☐	☐	☐	☐
Left		C2	C3	C4	C5	C6	C7	T1
		☐	☐	☐	☐	☐	☐	☐

Is there a comment on the neck examination that should be keypunched?

Yes ☐ No ☐

If yes, please fill in: _____

_____

UPPER EXTREMITY

Right shoulder range of motion

Is the range of motion of the right shoulder completely normal?

Yes ☐ (skip to motor power) No ☐ (continue below)

Range of motion

Flexion	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Extension	0	5	10	15	20	25	30	35	40	
	☐	☐	☐	☐	☐	☐	☐	☐	☐	
Internal Rotation	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
External Rotation	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Abduction	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Adduction	0	5	10	15	20	25				
	☐	☐	☐	☐	☐	☐				
Elevation	90		120		150		180			
	☐		☐		☐		☐			

Motor Power

Is the motor power of the right shoulder completely normal?

Yes ☐ (skip to reflexes) No ☐ (continue below)

(Mark one answer per muscle group)

Trapezius	1/5	2/5	3/5	4/5	5/5
	☐	☐	☐	☐	☐

Deltoid	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Biceps	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Triceps	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Brachialis	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Brachioradialis	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist extensors	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist flexors	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist suppinators	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist pronators	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Finger flexors and extensors	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Small intrinsics of the hand	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist extensors	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐

Reflexes

Are the reflexes of the right upper extremity completely normal?

Yes ☐ (skip to sensation) No ☐ (continue below)

Biceps	0 ☐	1+ ☐	2+ ☐	3+ ☐

Triceps	0	1+	2+	3+
	☐	☐	☐	☐
Brachioradialis	0	1+	2+	3+
	☐	☐	☐	☐

Sensation

Is sensation in the right upper extremity completely normal?

Yes ☐ (skip to pulses) No ☐ (continue below)

Dermatome	C5	Normal ☐	Abnormal ☐
	C6	Normal ☐	Abnormal ☐
	C7	Normal ☐	Abnormal ☐
	C8	Normal ☐	Abnormal ☐
	T1	Normal ☐	Abnormal ☐

Pulses

Are pulses in the right upper extremity completely normal?

Yes ☐ (skip to shoulder tenderness) No ☐ (continue below)

Brachial	Normal ☐	Abnormal ☐	**Adson**	Negative ☐
Radial	Normal ☐	Abnormal ☐		Positive ☐
Ulnar	Normal ☐	Abnormal ☐		

Tenderness

Is there abnormal tenderness in the right shoulder?

Yes ☐ (continue below) No ☐ (skip to shoulder ROM)

Bicipital tenderness

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Subacromial tenderness

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Pain on elevation of arm against resistance at subacromial space

Yes ☐ No ☐

Left shoulder range of motion

Is the range of motion of the left shoulder completely normal?

Yes ☐ (skip to motor power) No ☐ (continue below)

Range of motion

Flexion	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Extension	0	5	10	15	20	25	30	35	40	
	☐	☐	☐	☐	☐	☐	☐	☐	☐	
Internal Rotation	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
External Rotation	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Abduction	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Adduction	0	5	10	15	20	25				
	☐	☐	☐	☐	☐	☐				
Elevation	90		120		150		180			
	☐		☐		☐		☐			

Motor Power

Is the motor power of the left upper extremity completely normal?

Yes ☐ (skip to reflexes) No ☐ (continue below)

(Mark one answer per muscle group)

Trapezius	1/5	2/5	3/5	4/5	5/5
	☐	☐	☐	☐	☐
Deltoid	1/5	2/5	3/5	4/5	5/5
	☐	☐	☐	☐	☐
Biceps	1/5	2/5	3/5	4/5	5/5
	☐	☐	☐	☐	☐
Triceps	1/5	2/5	3/5	4/5	5/5
	☐	☐	☐	☐	☐

Brachialis	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Brachioradialis	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist extensors	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist flexors	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist suppinators	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist pronators	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Finger flexors and extensors	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Small intrinsics of the hand	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist extensors	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐

Reflexes

Are the reflexes of the left upper extremity completely normal?

Yes ☐ (skip to sensation) No ☐ (continue below)

Biceps	0 ☐	1+ ☐	2+ ☐	3+ ☐
Triceps	0 ☐	1+ ☐	2+ ☐	3+ ☐
Brachioradialis	0 ☐	1+ ☐	2+ ☐	3+ ☐

Sensation

Is sensation in the left upper extremity completely normal?

Yes ☐ (skip to pulses) No ☐ (continue below)

Dermatome	C5	Normal ☐	Abnormal ☐
	C6	Normal	Abnor
mal ☐			
	C7	Normal ☐	Abnormal ☐
	C8	Normal ☐	Abnormal ☐
	T1	Normal ☐	Abnormal ☐

Pulses

Ar
e pulses in the left upper extremity completely normal?

Yes ☐ (skip to shoulder derness) No ☐ (continue below)

Brachial	Normal ☐	Abnormal ☐	**Adson**	Negative ☐	
Radial	N				
ormal ☐	Abnormal ☐		Positive ☐		
Ulnar	Normal	Abnorm			
al					
☐					

Tenderness

Is there abnormal tenderness in the left shoulder?

Yes ☐ (continue below) No ☐ (skip to shoulder ROM)

Bicipital tenderness

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Subacromial tenderness

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Pain on elevation of arm against resistance at subacromial space

Yes ☐ No ☐

Is there a comment on the shoulder examination that should be keypunched?

Yes ☐ No ☐

If yes, please fill in: _____

_____

ELBOW

Right elbow

Is the examination of the right elbow completely normal?

Yes ☐ (skip to left elbow) No ☐ (continue below)

Lateral epicondylar tenderness

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Medial epicondylar tenderness

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Range of motion

Flexion	0	30	60	90	120	150
	☐	☐	☐	☐	☐	☐
Extension	150	120	90	60	30	0
	☐	☐	☐	☐	☐	☐

Radicular pain at ulnar groove Yes ☐ No ☐

Left elbow

Is the examination of the left elbow completely normal?

Yes ☐ (skip to wrist, hand, & fingers) No ☐ (continue below)

Lateral epicondylar tenderness

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Medial epicondylar tenderness

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Range of motion

Flexion	0	30	60	90	120	150
	☐	☐	☐	☐	☐	☐
Extension	150	120	90	60	30	0
	☐	☐	☐	☐	☐	☐

Radicular pain at ulnar groove Yes ☐ No ☐

Is there a comment about the elbow examination that should be keypunched?
Yes ☐ (fill out) No ☐ (skip to next question)

If yes, please fill in: _____

_____

WRIST, HAND, & FINGERS

Right Wrist

Is range of motion of the right wrist completely normal?

Yes ☐ (skip to left wrist) No ☐ (continue below)

	0	15	30	45	60	75	90
Dorsiflexion	☐	☐	☐	☐	☐	☐	☐
Palmer flexion	☐	☐	☐	☐	☐	☐	☐
Radial deviation	☐	☐	☐	☐	☐	☐	☐
Ulnar deviation	☐	☐	☐	☐	☐	☐	☐

Left Wrist

Is range of motion of the left wrist completely normal?

Yes ☐ (skip to right hand) No ☐ (continue below)

	0	15	30	45	60	75	90
Dorsiflexion	☐	☐	☐	☐	☐	☐	☐
Palmer flexion	☐	☐	☐	☐	☐	☐	☐
Radial deviation	☐	☐	☐	☐	☐	☐	☐
Ulnar deviation	☐	☐	☐	☐	☐	☐	☐

Right Hand

Pain upon palpation of dorsal compartment
Yes ☐ (specify below) No ☐ (skip to volar compartment)

Location	1	2	3	4	5
	☐	☐	☐	☐	☐

Pain upon palpation of volar compartment
Yes ☐ (specify below) No ☐ (continue with next question)

Location	1	2	3	4	5
	☐	☐	☐	☐	☐

Is there a scar from carpal tunnel surgery on the right hand? Yes ☐ No ☐

Phalen' sign	Positive ☐	Negative ☐
Tinel's sign	Positive ☐	Negative ☐
Finkelstein test	Positive ☐	Negative ☐

Palpable masses

Ganglion cyst	Yes ☐	No ☐
Trigger finger	Yes ☐	No ☐
Other mass	Yes ☐	No ☐

Inspection observation not noted above
Yes ☐ No ☐

Comments: _____

Left Hand

Pain upon palpation of dorsal compartment
Yes ☐ (specify below) No ☐ (skip to volar compartment)

Location	1	2	3	4	5
	☐	☐	☐	☐	☐

Pain upon palpation of volar compartment
Yes ☐ (specify below) No ☐ (continue with next question)

Location	1	2	3	4	5
	☐	☐	☐	☐	☐

Is there a scar from carpal tunnel surgery on the right hand? Yes ☐ No ☐

Phalen' sign	Positive ☐	Negative ☐
Tinel's sign	Positive ☐	Negative ☐
Finkelstein test	Positive ☐	Negative ☐

Palpable masses

Ganglion cyst	Yes ☐	No ☐
Trigger finger	Yes ☐	No ☐
Other mass	Yes ☐	No ☐

Inspection observation not noted above

Yes ☐ No ☐

Comments: _____

BACK

Is inspection of the back completely normal?

Yes ☐ (skip to ROM) No ☐ (continue below)

Spine straight	Yes ☐	No ☐
Shoulders and pelvis level	Yes ☐	No ☐
Walk normally on heels	Yes ☐	No ☐
Walk normally on toes	Yes ☐	No ☐
Can tandem walk normally	Yes ☐	No ☐
Able to squat normally	Yes ☐	No

ROM

Is range of motion of the back completely normal?

Yes ☐ (skip to straight leg raising) No ☐ (continue below)

Flexion	0 ☐	10 ☐	20 ☐	30 ☐	40 ☐	50 ☐	60 ☐	70 ☐	80 ☐	90 ☐

Painful locking of the low back on flexion Yes ☐ No ☐

Pain on flexion Yes ☐ No ☐

Extension	0 ☐	5 ☐	10 ☐	15 ☐	20 ☐	25 ☐	30 ☐

Pain on extension Yes ☐ No ☐

Right lateral deviation	0 ☐	10 ☐	20 ☐	30 ☐	40 ☐	45 ☐

Pain on right lateral deviation Yes ☐ No ☐

Left lateral deviation 0 10 20 30 40 45
☐ ☐ ☐ ☐ ☐ ☐

Pain on left lateral deviation Yes ☐ No ☐

Rotation to right 0 10 20 30 40 45
☐ ☐ ☐ ☐ ☐ ☐

Pain on right rotation Yes ☐ No ☐

Rotation to left 0 10 20 30 40 45
☐ ☐ ☐ ☐ ☐ ☐

Pain on left rotation Yes ☐ No ☐

Sitting

Straight leg raising (positive considered pain radiating from back to hip and lower extremity)

Right Yes ☐ No ☐ Left Yes ☐ No ☐

Sensation

Is sensation in the lower extremity completely normal?

Yes ☐ (skip to motor power) No ☐ (continue below)

Right thigh/leg sensation

L3	Normal ☐	Abnormal ☐
L4	Normal ☐	Abnormal ☐
L5	Normal ☐	Abnormal ☐
S1	Normal ☐	Abnormal ☐

Left thigh/leg sensation

L3	Normal ☐	Abnormal ☐
L4	Normal ☐	Abnormal ☐
L5	Normal ☐	Abnormal ☐
S1	Normal ☐	Abnormal ☐

Motor Power

Is motor power in the right lower extremity completely normal?

Yes ☐ (skip to motor power for left side) No ☐ (continue below)

Right

Quadriceps	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Hamstrings	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Anterior tibialis	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Posterior tibialis	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Peroneals	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Gastrocnemius	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Extensor hallucis longus	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐

Left

Is motor power in the left lower extremity completely normal?

Yes ☐ (skip to reflexes) No ☐ (continue below)

Quadriceps	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Hamstrings	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Anterior tibialis	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Posterior tibialis	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Peroneals	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐

Gastrocnemius	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Extensor hallucis longus	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐

Reflexes

Are lower extremity reflexes completely normal?

Yes ☐ (skip to supine) No ☐ (continue below)

Right

Patellar	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
Achilles	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐

Left

Patellar	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
Achilles	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐

Supine

Leg lengths (anterior superior iliac spine to tip of medial malleolus)

Are leg lengths equal? Yes ☐ (skip to sit-up) No ☐ (continue below)

Right (cm): _____ Left (cm): _____

Sit-up / thigh tenderness

Able to perform sit up normally Yes ☐ No ☐

Tenderness to thigh muscles?

Right Yes ☐ No ☐ Left Yes ☐ No ☐

Medical Exam Form

UAW-FORD ERGONOMIC STUDY PHYSICAL EXAM

Name: _____

Study Site Trip 1 ☐ Trip 2 ☐ Trip 3 ☐ Trip 4 ☐ Trip 5 ☐

Day of Week Mon ☐ Tues ☐ Wed ☐ Thur ☐ Fri ☐

Examiner SF ☐ AS ☐ CK ☐ WA ☐ Other ☐

This Exam is Completely Normal Yes ☐ No ☐

Hand Dominance Right ☐ Left ☐

NECK

Is examination of the neck completely normal?

Yes ☐ (skip to right shoulder) No ☐ (continue below)

Range of motion in degrees

Flexion	0	5	10	15	20	25	30	35	40	45
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Extension	0	5	10	15	20	25	30	35	40	45
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Lateral Deviation

Right	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Left	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Right Rotation	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Left Rotation	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Tenderness to palpation along spinous processes

Yes ☐ (proceed) No ☐ (skip to next series)

Spinous processes and soft tissue

Tenderness	0	1	2	3	4	5	6	7	8	9	10
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Location	C2	C3	C4	C5	C6	C7	T1				
	☐	☐	☐	☐	☐	☐	☐				

Spasm of soft tissue

Yes ☐ (proceed) No ☐ (skip to next series)

Location

Right	C2	C3	C4	C5	C6	C7	T1	
		☐	☐	☐	☐	☐	☐	☐
Left		C2	C3	C4	C5	C6	C7	T1
		☐	☐	☐	☐	☐	☐	☐

Is there a comment on the neck examination that should be keypunched?

Yes ☐ No ☐

If yes, please fill in: _____

_____

UPPER EXTREMITY

Right shoulder range of motion

Is the range of motion of the right shoulder completely normal?

Yes ☐ (skip to motor power) No ☐ (continue below)

Range of motion

Flexion	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Extension	0	5	10	15	20	25	30	35	40	
	☐	☐	☐	☐	☐	☐	☐	☐	☐	
Internal Rotation	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
External Rotation	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Abduction	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Adduction	0	5	10	15	20	25				
	☐	☐	☐	☐	☐	☐				
Elevation	90		120		150		180			
	☐		☐		☐		☐			

Motor Power

Is the motor power of the right shoulder completely normal?

Yes ☐ (skip to reflexes) No ☐ (continue below)

(Mark one answer per muscle group)

Trapezius	1/5	2/5	3/5	4/5	5/5
	☐	☐	☐	☐	☐

Deltoid	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Biceps	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Triceps	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Brachialis	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Brachioradialis	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist extensors	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist flexors	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist suppinators	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist pronators	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Finger flexors and extensors	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Small intrinsics of the hand	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist extensors	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐

Reflexes

Are the reflexes of the right upper extremity completely normal?

Yes ☐ (skip to sensation) No ☐ (continue below)

Biceps	0 ☐	1+ ☐	2+ ☐	3+ ☐

Triceps	0	1+	2+	3+
	☐	☐	☐	☐
Brachioradialis	0	1+	2+	3+
	☐	☐	☐	☐

Sensation

Is sensation in the right upper extremity completely normal?

Yes ☐ (skip to pulses) No ☐ (continue below)

Dermatome	C5	Normal ☐	Abnormal ☐
	C6	Normal ☐	Abnormal ☐
	C7	Normal ☐	Abnormal ☐
	C8	Normal ☐	Abnormal ☐
	T1	Normal ☐	Abnormal ☐

Pulses

Are pulses in the right upper extremity completely normal?

Yes ☐ (skip to shoulder tenderness) No ☐ (continue below)

Brachial	Normal ☐	Abnormal ☐	**Adson**	Negative ☐
Radial	Normal ☐	Abnormal ☐		Positive ☐
Ulnar	Normal ☐	Abnormal ☐		

Tenderness

Is there abnormal tenderness in the right shoulder?

Yes ☐ (continue below) No ☐ (skip to shoulder ROM)

Bicipital tenderness

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Subacromial tenderness

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Pain on elevation of arm against resistance at subacromial space

Yes ☐ No ☐

Left shoulder range of motion

Is the range of motion of the left shoulder completely normal?

Yes ☐ (skip to motor power) No ☐ (continue below)

Range of motion

Flexion	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Extension	0	5	10	15	20	25	30	35	40	
	☐	☐	☐	☐	☐	☐	☐	☐	☐	
Internal Rotation	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
External Rotation	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Abduction	0	10	20	30	40	50	60	70	80	90
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Adduction	0	5	10	15	20	25				
	☐	☐	☐	☐	☐	☐				
Elevation	90		120		150		180			
	☐		☐		☐		☐			

Motor Power

Is the motor power of the left upper extremity completely normal?

Yes ☐ (skip to reflexes) No ☐ (continue below)

(Mark one answer per muscle group)

Trapezius	1/5	2/5	3/5	4/5	5/5
	☐	☐	☐	☐	☐
Deltoid	1/5	2/5	3/5	4/5	5/5
	☐	☐	☐	☐	☐
Biceps	1/5	2/5	3/5	4/5	5/5
	☐	☐	☐	☐	☐
Triceps	1/5	2/5	3/5	4/5	5/5
	☐	☐	☐	☐	☐

Brachialis	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Brachioradialis	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist extensors	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist flexors	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist suppinators	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist pronators	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Finger flexors and extensors	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Small intrinsics of the hand	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Forearm and wrist extensors	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐

Reflexes

Are the reflexes of the left upper extremity completely normal?

Yes ☐ (skip to sensation) No ☐ (continue below)

Biceps	0 ☐	1+ ☐	2+ ☐	3+ ☐
Triceps	0 ☐	1+ ☐	2+ ☐	3+ ☐
Brachioradialis	0 ☐	1+ ☐	2+ ☐	3+ ☐

Sensation

Is sensation in the left upper extremity completely normal?

Yes ☐ (skip to pulses) No ☐ (continue below)

Dermatome	C5	Normal ☐	Abnormal ☐
	C6	Normal	Abnor
mal ☐			
	C7	Normal ☐	Abnormal ☐
	C8	Normal ☐	Abnormal ☐
	T1	Normal ☐	Abnormal ☐

Pulses

Ar
e pulses in the left upper extremity completely normal?

Yes ☐ (skip to shoulder derness) No ☐ (continue below)

Brachial	Normal ☐	Abnormal ☐	**Adson**	Negative ☐	
Radial	N				
ormal ☐	Abnormal ☐		Positive ☐		
Ulnar	Normal	Abnorm			
al					
☐					

Tenderness

Is there abnormal tenderness in the left shoulder?

Yes ☐ (continue below) No ☐ (skip to shoulder ROM)

Bicipital tenderness

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Subacromial tenderness

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Pain on elevation of arm against resistance at subacromial space

Yes ☐ No ☐

Is there a comment on the shoulder examination that should be keypunched?

Yes ☐ No ☐

If yes, please fill in: _____

_____

ELBOW

Right elbow

Is the examination of the right elbow completely normal?

Yes ☐ (skip to left elbow) No ☐ (continue below)

Lateral epicondylar tenderness

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Medial epicondylar tenderness

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Range of motion

Flexion	0	30	60	90	120	150
	☐	☐	☐	☐	☐	☐
Extension	150	120	90	60	30	0
	☐	☐	☐	☐	☐	☐

Radicular pain at ulnar groove Yes ☐ No ☐

Left elbow

Is the examination of the left elbow completely normal?

Yes ☐ (skip to wrist, hand, & fingers) No ☐ (continue below)

Lateral epicondylar tenderness

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Medial epicondylar tenderness

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Range of motion

Flexion	0	30	60	90	120	150
	☐	☐	☐	☐	☐	☐
Extension	150	120	90	60	30	0
	☐	☐	☐	☐	☐	☐

Radicular pain at ulnar groove Yes ☐ No ☐

Is there a comment about the elbow examination that should be keypunched?
Yes ☐ (fill out) No ☐ (skip to next question)

If yes, please fill in: _____

_____

WRIST, HAND, & FINGERS

Right Wrist

Is range of motion of the right wrist completely normal?

Yes ☐ (skip to left wrist) No ☐ (continue below)

	0	15	30	45	60	75	90
Dorsiflexion	☐	☐	☐	☐	☐	☐	☐
Palmer flexion	☐	☐	☐	☐	☐	☐	☐
Radial deviation	☐	☐	☐	☐	☐	☐	☐
Ulnar deviation	☐	☐	☐	☐	☐	☐	☐

Left Wrist

Is range of motion of the left wrist completely normal?

Yes ☐ (skip to right hand) No ☐ (continue below)

	0	15	30	45	60	75	90
Dorsiflexion	☐	☐	☐	☐	☐	☐	☐
Palmer flexion	☐	☐	☐	☐	☐	☐	☐
Radial deviation	☐	☐	☐	☐	☐	☐	☐
Ulnar deviation	☐	☐	☐	☐	☐	☐	☐

Right Hand

Pain upon palpation of dorsal compartment
Yes ☐ (specify below) No ☐ (skip to volar compartment)

Location	1	2	3	4	5
	☐	☐	☐	☐	☐

Pain upon palpation of volar compartment
Yes ☐ (specify below) No ☐ (continue with next question)

Location	1	2	3	4	5
	☐	☐	☐	☐	☐

Is there a scar from carpal tunnel surgery on the right hand? Yes ☐ No ☐

Phalen' sign	Positive ☐	Negative ☐
Tinel's sign	Positive ☐	Negative ☐
Finkelstein test	Positive ☐	Negative ☐

Palpable masses

Ganglion cyst	Yes ☐	No ☐
Trigger finger	Yes ☐	No ☐
Other mass	Yes ☐	No ☐

Inspection observation not noted above
Yes ☐ No ☐

Comments: _____

Left Hand

Pain upon palpation of dorsal compartment
Yes ☐ (specify below) No ☐ (skip to volar compartment)

Location	1	2	3	4	5
	☐	☐	☐	☐	☐

Pain upon palpation of volar compartment
Yes ☐ (specify below) No ☐ (continue with next question)

Location	1	2	3	4	5
	☐	☐	☐	☐	☐

Is there a scar from carpal tunnel surgery on the right hand? Yes ☐ No ☐

Phalen' sign	Positive ☐	Negative ☐
Tinel's sign	Positive ☐	Negative ☐
Finkelstein test	Positive ☐	Negative ☐

Palpable masses

Ganglion cyst	Yes ☐	No ☐
Trigger finger	Yes ☐	No ☐
Other mass	Yes ☐	No ☐

Inspection observation not noted above

Yes ☐ No ☐

Comments: _____

BACK

Is inspection of the back completely normal?

Yes ☐ (skip to ROM) No ☐ (continue below)

Spine straight	Yes ☐	No ☐
Shoulders and pelvis level	Yes ☐	No ☐
Walk normally on heels	Yes ☐	No ☐
Walk normally on toes	Yes ☐	No ☐
Can tandem walk normally	Yes ☐	No ☐
Able to squat normally	Yes ☐	No

ROM

Is range of motion of the back completely normal?

Yes ☐ (skip to straight leg raising) No ☐ (continue below)

Flexion	0 ☐	10 ☐	20 ☐	30 ☐	40 ☐	50 ☐	60 ☐	70 ☐	80 ☐	90 ☐

Painful locking of the low back on flexion Yes ☐ No ☐

Pain on flexion Yes ☐ No ☐

Extension	0 ☐	5 ☐	10 ☐	15 ☐	20 ☐	25 ☐	30 ☐

Pain on extension Yes ☐ No ☐

Right lateral deviation	0 ☐	10 ☐	20 ☐	30 ☐	40 ☐	45 ☐

Pain on right lateral deviation Yes ☐ No ☐

Left lateral deviation 0 10 20 30 40 45
☐ ☐ ☐ ☐ ☐ ☐

Pain on left lateral deviation Yes ☐ No ☐

Rotation to right 0 10 20 30 40 45
☐ ☐ ☐ ☐ ☐ ☐

Pain on right rotation Yes ☐ No ☐

Rotation to left 0 10 20 30 40 45
☐ ☐ ☐ ☐ ☐ ☐

Pain on left rotation Yes ☐ No ☐

Sitting

Straight leg raising (positive considered pain radiating from back to hip and lower extremity)

Right Yes ☐ No ☐ Left Yes ☐ No ☐

Sensation

Is sensation in the lower extremity completely normal?

Yes ☐ (skip to motor power) No ☐ (continue below)

Right thigh/leg sensation

L3	Normal ☐	Abnormal ☐
L4	Normal ☐	Abnormal ☐
L5	Normal ☐	Abnormal ☐
S1	Normal ☐	Abnormal ☐

Left thigh/leg sensation

L3	Normal ☐	Abnormal ☐
L4	Normal ☐	Abnormal ☐
L5	Normal ☐	Abnormal ☐
S1	Normal ☐	Abnormal ☐

Motor Power

Is motor power in the right lower extremity completely normal?

Yes ☐ (skip to motor power for left side) No ☐ (continue below)

Right

Quadriceps	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Hamstrings	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Anterior tibialis	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Posterior tibialis	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Peroneals	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Gastrocnemius	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Extensor hallucis longus	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐

Left

Is motor power in the left lower extremity completely normal?

Yes ☐ (skip to reflexes) No ☐ (continue below)

Quadriceps	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Hamstrings	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Anterior tibialis	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Posterior tibialis	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Peroneals	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐

Gastrocnemius	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐
Extensor hallucis longus	1/5 ☐	2/5 ☐	3/5 ☐	4/5 ☐	5/5 ☐

Reflexes

Are lower extremity reflexes completely normal?

Yes ☐ (skip to supine) No ☐ (continue below)

Right

Patellar	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
Achilles	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐

Left

Patellar	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
Achilles	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐

Supine

Leg lengths (anterior superior iliac spine to tip of medial malleolus)

Are leg lengths equal? Yes ☐ (skip to sit-up) No ☐ (continue below)

Right (cm): _____ Left (cm): _____

Sit-up / thigh tenderness

Able to perform sit up normally Yes ☐ No ☐

Tenderness to thigh muscles?

Right Yes ☐ No ☐ Left Yes ☐ No ☐

Pulses

Are lower extremity pulses completely normal?

Yes ☐ (skip to prone) No ☐ (continue below)

Right

Popliteal	1/4 ☐	2/4 ☐	3/4 ☐	4/4 ☐
Posterior tibial	1/4 ☐	2/4 ☐	3/4 ☐	4/4 ☐
Dorsalis pedis	1/4 ☐	2/4 ☐	3/4 ☐	4/4 ☐

Left

Popliteal	1/4 ☐	2/4 ☐	3/4 ☐	4/4 ☐
Posterior tibial	1/4 ☐	2/4 ☐	3/4 ☐	4/4 ☐
Dorsalis pedis	1/4 ☐	2/4 ☐	3/4 ☐	4/4 ☐

Prone

Tenderness to palpation of spinous processes Yes ☐ No ☐

Location	L1	L2	L3	L4	L5	S1
	☐	☐	☐	☐	☐	☐

Tenderness to palpation of paraspinal muscles

Right Yes ☐ No ☐

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Spasm Yes ☐ No ☐

Left Yes ☐ No ☐

0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Spasm Yes ☐ No ☐

Is there a comment concerning the back examination?

Yes ☐ (continue below) No ☐ (skip to hip exam)

If yes, please fill in: _____

_____

HIPS

Right

Is examination of the right hip completely normal?

Yes ☐ (skip to left) No ☐ (continue below)

ROM

Flexion	0	30	60	90	120	150		
	☐	☐	☐	☐	☐	☐		
Extension	150	120	90	60	30	0		
	☐	☐	☐	☐	☐	☐		
Abduction	0	10	20	30	40	50		
	☐	☐	☐	☐	☐	☐		
Adduction	0	5	10	15	20	25		
	☐	☐	☐	☐	☐	☐		
External rotation	0	15	30	45	60	75	90	
	☐	☐	☐	☐	☐	☐	☐	
Internal rotation	0	5	10	15	20	25	30	35
	☐	☐	☐	☐	☐	☐	☐	☐

Tenderness to greater trochanter Yes ☐ No ☐

Left

Is examination of the left hip completely normal?

Yes ☐ (skip to knee) No ☐ (continue below)

ROM

Flexion	0	30	60	90	120	150
	☐	☐	☐	☐	☐	☐

Extension	150	120	90	60	30	0		
	☐	☐	☐	☐	☐	☐		
Abduction	0	10	20	30	40	50		
	☐	☐	☐	☐	☐	☐		
Adduction	0	5	10	15	20	25		
	☐	☐	☐	☐	☐	☐		
External rotation	0	15	30	45	60	75	90	
	☐	☐	☐	☐	☐	☐	☐	
Internal rotation	0	5	10	15	20	25	30	35
	☐	☐	☐	☐	☐	☐	☐	☐

Tenderness to greater trochanter Yes ☐ No ☐

KNEE

Right

Is examination of the right knee completely normal?

Yes ☐ (skip to left) No ☐ (continue below)

ROM

Flexion	0	30	60	90	120	150
	☐	☐	☐	☐	☐	☐
Extension	150	120	90	60	30	0
	☐	☐	☐	☐	☐	☐

Tenderness to medial joint line and/or medial tibial flair Yes ☐ No ☐
Tenderness to lateral joint line and/or lateral tibial flair Yes ☐ No ☐
Tenderness to patellar tendon Yes ☐ No ☐

Left

Is examination of the left knee completely normal?

Yes ☐ (skip to ankle and foot) No ☐ (continue below)

ROM

Flexion	0	30	60	90	120	150
	☐	☐	☐	☐	☐	☐
Extension	150	120	90	60	30	0
	☐	☐	☐	☐	☐	☐

Tenderness to medial joint line and/or medial tibial flair Yes ☐ No ☐
Tenderness to lateral joint line and/or lateral tibial flair Yes ☐ No ☐
Tenderness to patellar tendon Yes ☐ No ☐

ANKLE AND FOOT

Right

Is examination of the right ankle and foot completely normal?

Yes ☐ (skip to left) No ☐ (continue below)

ROM

Dorsiflexion	0 ☐	10 ☐	20 ☐	30 ☐
Plantar flexion	0 ☐	15 ☐	30 ☐	45 ☐

Soft tissue tenderness

Lateral malleolus/peroneal tendons	Yes ☐	No ☐
Medial malleolus/posterior tibial tendons	Yes ☐	No ☐
Arch present	Yes ☐	No ☐
Tenderness to plantar fascia	Yes ☐	No ☐

Left

Is examination of the left ankle and foot completely normal?

Yes ☐ (skip to end) No ☐ (continue below)

ROM

Dorsiflexion	0 ☐	10 ☐	20 ☐	30 ☐
Plantar flexion	0 ☐	15 ☐	30 ☐	45 ☐

Soft tissue tenderness

Lateral malleolus/peroneal tendons	Yes ☐	No ☐

Medial malleolus/posterior tibial tendons	Yes ☐	No ☐
Arch present	Yes ☐	No ☐
Tenderness to plantar fascia	Yes ☐	No ☐

Is there a comment concerning the lower extremity examination?
Yes ☐ No ☐

If yes, please fill in: _____

_____

Appendix [4]

Job Analysis Forms

Job Requirements for Task Analysis Form

12. Job ID #: _____

13. Date: mm/dd/yy

14. Facility: _____ 15. Team Member #'s: ___ scribe ___ observer

16. Time of day: ____:____ (military time)

17. Job cycle time: ____:____ (minutes / seconds)

18. Hours worked/day: ____ Typical hours/day: ____

19. PPE required: No ☐ Gloves ☐ Eyes ☐ Ears ☐ 20. Fit: Yes ☐ No ☐

21. Operator assessment: What's hardest part (specific task(s) of job?

_____

22. Operator assessment: What part(s) of your body is most challenged (affected)?

None	HW	LA/E	UA/S	T	N	HKF	L	R	B
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

23. Job Requirements [Heading]

24. Palm of hand used as hammer: _____ reps/cycle _____ reps/day

25. Knee used as hammer/kicker: _____ reps/cycle _____ reps/day

26. Knee used for boosting/lifting: _____ reps/cycle _____ reps/day

27. Operator kneeling required: _____ hours

28. Operator squatting required: _____ hours

29. Operator seated: _____ hours

30. Adequate back support: No ☐ Used ☐ Not Used ☐

31. Adequate foot support: No ☐ Used ☐ Not Used ☐

32. Mainly static (>1 minute):

No	H/W	LA/E	UA/S	T	N	HKF
☐	☐	☐	☐	☐	☐	☐

33. General Work Environment [Heading]

34. Constant monitoring required: No ☐ Yes ☐

35. Tight daily deadlines (quotas): No ☐ Yes ☐

36. Tightly paced work (machine paced): No ☐ Yes ☐

37. Piece rate: No ☐ Yes ☐

38. Whole Body Vibration (vibrating surface): _____ hours

39. Source of Vibration: _____

40. Cold temp: _____ hours hot temp: _____ hours

41. Lighting: _____ hours

42. Other environmental concerns: _____

43. Comments: _____

44. Standing: _____ hours

45. Stationary standing required: _____ hours

46. Sit/stand stool: No ☐ Used ☐ Not Used ☐

47. Walking required: _____ hours

48. Legs well supported and balanced posture: No ☐ Yes ☐

49. Anti-fatigue mats: No ☐ Used ☐ Not Used ☐

50. Adjustability: No ☐ Chair ☐ Floor ☐ Work Surface ☐

51. Specific ergonomic suggestion/concern: _____\

52. Hardest task: _____

53. Number of tasks: _____

54. Task 1 _____:_____ (hours/minutes)
Task 2 _____:_____ (hours/minutes)
Task 3 _____:_____ (hours/minutes)
Task 4 _____:_____ (hours/minutes)
Task 5 _____:_____ (hours/minutes)
Task 6 _____:_____ (hours/minutes)
Task 7 _____:_____ (hours/minutes)

55. Task 1 N/A ☐ Stress N/O ☐ S/A ☐
Task 2 N/A ☐ Stress N/O ☐ S/A ☐
Task 3 N/A ☐ Stress N/O ☐ S/A ☐
Task 4 N/A ☐ Stress N/O ☐ S/A ☐
Task 5 N/A ☐ Stress N/O ☐ S/A ☐
Task 6 N/A ☐ Stress N/O ☐ S/A ☐
Task 7 N/A ☐ Stress N/O ☐ S/A ☐

56. Task 1 Per/cycle ☐ Intermittent ☐ Infrequent ☐
Task 2 Per/cycle ☐ Intermittent ☐ Infrequent ☐
Task 3 Per/cycle ☐ Intermittent ☐ Infrequent ☐
Task 4 Per/cycle ☐ Intermittent ☐ Infrequent ☐
Task 5 Per/cycle ☐ Intermittent ☐ Infrequent ☐
Task 6 Per/cycle ☐ Intermittent ☐ Infrequent ☐
Task 7 Per/cycle ☐ Intermittent ☐ Infrequent ☐

OSHA Checklist Form

57. Job ID #: _____

58. Description: _____

59. Upper Extremity Risk Factors [Heading]

60. Identical/similar upper body motions repeated every few sec: _____ hours

61. Grip more than 10 pound load: _____ hours

62. Pinch more than 2 pounds: _____ hours

63. Neck: twist/bend (> 20 flex, > 5 ext., or 20 side): _____ hours

64. Unsupported arm during fine or precision work: _____ hours

65. Elbow above mid-torso (abduction): _____ hours

66. Rapid forearm rotation/resisting tool rotation: _____ hours

67. Wrist bend/deviate (> 20 flex, > 30 ext.): _____ hours

68. Fingers (forceful gripping): _____ hours

69. Hard/sharp objects press into skin (upper body): _____ hours

70. Hard/sharp objects press into skin (lower body): _____ hours

71. Localized vibration (hand/arm): _____ hours

72. Back and Lower Extremity Risk Factors [Heading]

73. Mild forward or side bending of torso (20-45 degrees): _____ hours

74. Severe forward bending of torso (> 45 degrees): _____ hours

75. Backward bending of torso (extension): _____ hours

76. Twisting torso: _____ hours

77. Repetitive ankle extension/flexion: _____ hours

78. Push/Pull Moderate load: _____ hours

79. Push/Pull Heavy load: _____ hours

80. Applicable manual material handling?
No ☐ up to 1 hour/day ☐ > 1 hour/day ☐

81. Manual Handling [Heading]

82. Average lift position: near ☐ middle ☐ far ☐

83. Average object weight (pounds): _____

84. Twisting torso during lifting: Yes ☐ No ☐

85. Lifting one-handed: Yes ☐ No ☐

86. Lift unstable loads: Yes ☐ No ☐

87. Lift between 1 to 5 times per minute: Yes ☐ No ☐

88. Lift 5 or more times per minute: Yes ☐ No ☐

89. Lifts above the shoulder: Yes ☐ No ☐

90. Carry objects 10 to 30 feet: Yes ☐ No ☐

91. Carry objects greater than 30 feet: Yes ☐ No ☐

92. Lift while seated or kneeling: Yes ☐ No ☐

UECTD Requirements Form

93. Job ID#: _____ 94. Task#: _____

95. Description: _____

96. Left ☐ Right ☐ Both ☐ Together ☐ Right same ☐ as left (mirror)

98. Left hand activity [Heading]

99. Hold ☐ Connect ☐ Motion ☐ Motion w/o force ☐ Other ☐

100. Object Description: _____

101. Size: XS ☐ S ☐ M ☐ L ☐

102. Wt. (lbs.): _____

103. Torso [Heading]

104. Upright ☐ Stoop ☐ Squat ☐ Kneel ☐ Seated ☐ Seat Ht: ____

105. Extension: No ☐ St: _____ Rp: _____

106. Flexion: No ☐ Ext ☐ 1/4 ☐ 1/2 ☐ 3/4 ☐ 1 ☐
Rp: _____ St: _____

107. Max Flexion: No diff ☐ 1/2 ☐ 3/4 ☐ 1 ☐ Rp: _____ St: ____

108. Lat. Flex: No ☐ Mid ☐ Extreme ☐ Left ☐ Right ☐
St: _____ Rp: _____

109. Twisting: No ☐ Mid ☐ Extreme ☐ Left ☐ Right ☐
St: _____ Rp: _____

110. Speed
- ☐ Extremely relaxed pace
- ☐ Taking one's own time

☐ "Normal" speed of motion

☐ Rushed, but able to keep up
☐ Rushed, barely/unable to keep up

111. Percent Duration Exertion <10 ☐ 10-29 ☐ 30-49 ☐ 50-70 ☐ >80 ☐

112. Intensity Light ☐ Somewhat hard ☐ Hard ☐ Very hard ☐ Nr max ☐

113. Right hand activity [Heading]

114. Hold ☐ Connect ☐ Motion ☐ Motion w/o force ☐ Other ☐

115. Object Description: _____

116. Size: XS ☐ S ☐ M ☐ L ☐

117. Wt. (lbs.): _____

118. Neck [Heading]

119. Extension: No ☐ St: _____ Rp: _____

120. Flexion: No ☐ Mid ☐ Extreme ☐ St: _____ Rp: _____

121. Max Flexion: No diff ☐ 1/2 ☐ 3/4 ☐ 1 ☐ Rp: _____St: ____

108. Lat. Flex: No ☐ Mid ☐ Extreme ☐ Left ☐ Right ☐
St: _____ Rp: _____

122. Side bend: No ☐ Left ☐ Right ☐ St: _____ Rp: _____

123. Twist: No ☐ Mid ☐ Extreme ☐ St: _____ Rp: _____

124. Job ID#: _____ 125. Task#: _____

126. Left Hand and Arm [Heading]

127. Object Postion [Heading]

128. Horizontal Distance: _____ Vertical Distance: _____

129. Lateral Zone: Front ☐ Side ☐ Rear ☐ Left ☐ Right ☐

130. Interface [Heading]

131. Object Surface condition: Good ☐ Poor ☐

132. Grip: Wrap ☐ Hook ☐ Contact ☐ Oblique ☐ Medial ☐
Pinch ☐ Press ☐

133. Grip/Pinch/Press: Rp: _____ St: _____

134. Low ☐ Mod ☐ High ☐ Match: _____ Measure: _____

135. Forceful tool kick/impact or torque: No ☐ Low ☐ High ☐ Rp: ____

136. Vibration (hand/arm): No ☐ Low ☐ High ☐ Time: _____

137. Vibration source: _____

138. Load wt/Force: _____ Time: _____

139. Hand/Wrist/LA/Elbow [Heading]

140. Finger motion: No ☐ Mod ☐ Rapid ☐

141. Flexion: No ☐ Middle ☐ Extreme ☐ St: _____ Rp: _____

142. Extension: No ☐ Middle ☐ Extreme ☐ St: _____ Rp: _____

143. Radial/Ulnar deviation: No ☐ St: _____ Rp: _____

144. Supine ☐ Prone ☐ Neutral ☐ Palm Out ☐ St: _____ Rp: _____

145. Forearm rotation: No ☐ Rp: _____

146. Upper Arm [Heading]

147. Shoulder(s) raised: No ☐ St: _____ Rp: _____

148. Upper arm abducted: No ☐ St: _____ Rp: _____

149. Right Hand and Arm [Heading]

150. Object Postion [Heading]

151. Horizontal Distance: _____ Vertical Distance: _____

152. Lateral Zone: Front ☐ Side ☐ Rear ☐ Left ☐ Right ☐

153. Interface [Heading]

154. Object Surface condition: Good ☐ Poor ☐

155. Grip: Wrap ☐ Hook ☐ Contact ☐ Oblique ☐ Medial ☐
Pinch ☐ Press ☐

156. Grip/Pinch/Press: Rp: _____ St: _____

157. Low ☐ Mod ☐ High ☐ Match: _____ Measure: _____

158. Forceful tool kick/impact or torque: No ☐ Low ☐ High ☐ Rp: ____

159. Vibration (hand/arm): No ☐ Low ☐ High ☐ Time: _____

160. Vibration source: _____

161. Load wt/Force: _____ Time: _____

162. Hand/Wrist/LA/Elbow [Heading]

163. Finger motion: No ☐ Mod ☐ Rapid ☐

164. Flexion: No ☐ Middle ☐ Extreme ☐ St: _____ Rp: _____

165. Extension: No ☐ Middle ☐ Extreme ☐ St: _____ Rp: _____

166. Radial/Ulnar deviation: No ☐ St: _____ Rp: _____

167. Supine ☐ Prone ☐ Neutral ☐ Palm Out ☐ St: _____ Rp: _____

168. Forearm rotation: No ☐ Rp: _____

169. Upper Arm [Heading]

170. Shoulder(s) raised: No ☐ St: _____ Rp: _____

171. Upper arm abducted: No ☐ St: _____ Rp: _____

Manual Material Handling Form

172. Job ID#: _____ 173. Task#: _____

174. Description: _____

175. Hand(s) Used: Left ☐ Right ☐ Both ☐ Together ☐ Right same ☐ as left (mirror)

177. Coupling: good ☐ fair ☐ poor ☐

178. Object surface condition: good ☐ poor ☐

179. Grip: Wrap ☐ Hook ☐ Pinch ☐ Contact ☐

180. Object Manipulation (LEFT) [Heading]

181. Left Hand Activity: _____

182. Actions (lifts/lowers)/task: _____

183. Push ☐ Pull ☐ Lift ☐ Lower ☐ Carry ☐ Other ☐

184. Object Description: _____

185. Wt. (lbs.): _____ Size: XS ☐ S ☐ M ☐ L ☐

186. Load wt/force Ave: _____ Max: _____ Time: _____

187. Sustained push/pull force: _____ Time: _____ N/A ☐

188. Initial push/pull force: _____ Time: _____ N/A ☐

189. Carry/push/pull Distance (feet): _____ Height: Waist ☐ Chest ☐ Time: _____ N/A ☐

190. Load unstable or hands not at COM: No ☐ Yes ☐

191. Handhold width (dist between handholds): _____

192. Object Beginning/Origin [Heading]

193. Horizontal Distance: _____ 194. Vertical Distance: _____

195. Load Control: No ☐ Yes ☐

196. Lateral Zone: Front ☐ Side ☐ Rear ☐ Left ☐ Right ☐

197. Torso [Heading]

198. Torso Posture: Upright ☐ Stoop ☐ Squat ☐ Kneel ☐ Seated ☐
Seat Ht: _____

199. Extension/Flexion: No ☐ Ext ☐ 1/4 ☐ 1/2 ☐ 3/4 ☐ 1 ☐
Rp: _____ St: _____

200. Max Flexion: No diff ☐ 1/2 ☐ 3/4 ☐ 1 ☐
Rp: _____ St: _____

201. Object End/Destination [Heading]

202. Horizontal Distance: _____ 203. Vertical Distance: _____

204. Load Control: No ☐ Yes ☐

205. Lateral Zone: Front ☐ Side ☐ Rear ☐ Left ☐ Right ☐

206. Torso [Heading]

207. Torso Posture: Upright ☐ Stoop ☐ Squat ☐ Kneel ☐ Seated ☐
Seat Ht: _____

208. Extension/Flexion: No ☐ Ext ☐ 1/4 ☐ 1/2 ☐ 3/4 ☐ 1 ☐
Rp: _____ St: _____

209. Max Flexion: No diff ☐ 1/2 ☐ 3/4 ☐ 1 ☐
Rp: _____ St: _____

210. Object Manipulation (RIGHT) [Heading]

211. Right Hand Activity: _____

212. Actions (lifts/lowers)/task: _____

213. Push ☐ Pull ☐ Lift ☐ Lower ☐ Carry ☐ Other ☐

214. Object Description: _____

215. Wt. (lbs.): _____ Size: XS ☐ S ☐ M ☐ L ☐

216. Load wt/force Ave: _____ Max: _____ Time: _____

217. Sustained push/pull force: _____ Time: _____ N/A ☐

218. Initial push/pull force: _____ Time: _____ N/A ☐

219. Carry/push/pull Distance (feet): _____ Height: Waist ☐ Chest ☐
Time: _____ N/A ☐

220. Load unstable or hands not at COM: No ☐ Yes ☐

221. Object Beginning/Origin [Heading]

222. Horizontal Distance: _____ 223. Vertical Distance: _____

224. Load Control: No ☐ Yes ☐

225. Lateral Zone: Front ☐ Side ☐ Rear ☐ Left ☐ Right ☐

226. Lat. Flex: No ☐ Mid ☐ Extreme ☐ Left ☐ Right ☐
St: _____ Rp: _____

227. Twisting: No ☐ Mid ☐ Extreme ☐ Left ☐ Right ☐
St: _____ Rp: _____

228. Object End/Destination [Heading]

229. Horizontal Distance: _____ 230. Vertical Distance: _____

231. Load Control: No ☐ Yes ☐

232. Lateral Zone: Front ☐ Side ☐ Rear ☐ Left ☐ Right ☐

233. Lat. Flex: No ☐ Mid ☐ Extreme ☐ Left ☐ Right ☐
St: _____ Rp: _____

234. Twisting: No ☐ Mid ☐ Extreme ☐ Left ☐ Right ☐
St: _____ Rp: _____

Appendix [5]

Job Analysis Forms – Question Definitions

		Job Requirements Form
1	Process Number	The Ford identification number for this job. Include brief verbal job description (i.e., left tail light install).
2	Job ID #:	Identifier used to link all forms related to a particular job.
3	Drot #:	Identifier for a supervision area (daily report of time), somewhat like department.
4	Subject Name:	Hey! This is obvious!
5	Ford ID #:	The Ford Identification number is the last four digits of the employees social security #.
6	Experience:	How much experience the employee has on this particular job (not jobs like it, but this job). Years, months, or weeks. Use the appropriate time frame.
7	Gender:	Enter the employee's gender.
8	Height:	Enter the employee's height in inches. If the employee gives an obviously erroneous height, use your best estimate.
9	Dominant hand:	Is the employee right-handed, left-handed, or ambi-dexterous. If the employee uses both hands equally well for the jobs they perform, mark ambi-dexterous.
10	Informed Consent Form	Mark whether the employee has completed the informed consent paperwork at medical or at the job site. If the IC must be completed at the job site, make sure that the employee gets a signed copy from the ergonomist team before proceeding.
11	Video tape approval	This indicates whether the employee has given approval for video taping. If the employee does not wish to be video taped and is the only employee who has consented to having their job analyzed, complete the job analysis without taping the employee.

12	Job ID #:	Identifier used to link all forms related to a particular job.
13	Date:	The date the data is collected.
14	Facility	The facility visited (number 1-6).
15	Team member numbers:	Identifiers for the ergonomists analyzing the job. Each ergonomist is given a number.
16	Time of day:	Military time of day.
17	Job cycle time:	Cycle time as measured (minutes : seconds) on-site by the team.
17	Cycle time:	How the cycle time was derived. "Timed" indicates that the job was observed and timed. "Calc from prod" indicates that the time was computed from the daily production numbers (used when the line runs in "spurts"). "N/A" no applicable cycle exists.
18	Hours Worked / Day:	Hours that the employee is working per day NOW
18	Typical hours worked/Day	Hours that employees on this job NORMALLY work per day
19	PPE required:	Personal protective equipment that is required for the job
20	Fit	does the PPE fit, particularly the gloves
21	Operator assessment: What's Hardest Part (specific task(s)) of Job?	What does the operator think is the most difficult aspect of this job
22	Operator assessment: What part(s) of your body is most challenged (affected)?	Where does the operator think that this job is affecting his/her body. What part(s) of the body are "worked" hardest. If the operator has no concerns or feels that the job is "easy", choose "none".
23	Job Requirements	These are questions that should be applied to the entire job, not on task-by-task basis.

24	Palm of hand used as hammer:	"Reps/cycle": the number of times / cycle that the palm of the hand is used to strike. "Reps/day": is the total number of times it is used to strike during intermittent tasks (do not include strikes that occur during each cycle).
25	Knee used as hammer/kicker:	"Reps/cycle": the number of times / cycle that the knee is used to strike or push. "Reps/day": is the total number of times it is used to strike during intermittent tasks (do not include strikes that occur during each cycle).
26	Knee used for boosting:	"Reps/cycle": the number of times / cycle that the worker uses their knee for boosting or lifting. "Reps/day": is the total number of times it is used to boost during intermittent tasks (do not include strikes that occur during each cycle).
27	Operator kneeling required:	The number of hours that the worker must kneel during the work shift (CTH).
28	Operator squatting required:	The number of hours that the worker must squat during the work shift (CTH).
29	Operator seated:	The number of hours that the worker is seated during the work shift (CTH).
30	Adequate back support provided for seated work?	Is adequate back support provided for the seated work?
31	Adequate foot support for seated work	Is adequate foot support provided for the seated work?
32	Mainly static (> 1 minute):	Are any of the body parts held in a "mainly" (mostly) static position for > 1 minute? This does not imply completely continuous static posture, but a "mostly" static posture.
33	General Work Environment	This section describes local work place and "environment" for the job
34	Constant monitoring required:	The operator is required to remain continuously vigilant (i.e., watching a computer screen and waiting for a change or inspecting and removing bad parts from a conveyor belt)

35	Tight daily deadlines (quotas):	Operator must produce a fixed quantity of product before the shift can end.
36	Tightly paced work (machine paced):	Little opportunity for operator discretion, must work at a speed dictated by the assembly line.
37	Piece rate:	There is incentive pay for each unit produced (operators are rewarded for working quickly).
38	Whole Body Vibration (vibrating surface):	The number of hours that the worker is exposed to whole body vibration (through chair or floor) during the shift. The number of hours is the cumulative total for the entire work shift, not necessarily consecutive (Cumulative Total Hours, CTH).
39	Source of vibration:	What is producing the whole body vibration.
40	Cold / Hot temperatures.	The number of hours that the worker is exposed to cold and hot temperatures, respectively (CTH). Intended for temperatures that have an "ergonomic impact" or effect (i.e., working in a refrigerated area or near a furnace).
41	Lighting:	The number of hours that the worker is exposed to poor lighting (low levels or harsh levels, CTH).
42	Other environmental concerns:	Simply write in any other environmental factors that may affect the worker.
43	Comments:	Any comments that may assist with the data reduction. Unusual or important data not solicited by the forms in some other way.
44	Standing:	The number of hours that the worker is standing (on their feet / upright) during the work shift (CTH). This is essentially "on feet" time and includes walking.
45	Stationary (no lower body movement):	The number of hours that the worker is standing and cannot freely move or position their legs (legs are "frozen" - cannot shift feet freely) during the work shift (CTH).

46	Sit/stand stool provided:	Is a sit/stand stool provided? Is it used or not used?
47	Walking required:	The number of hours that the worker must walk (CTH). Walking is defined as 2 mph and purposeful (required by job). Walking does not include following a slow moving assembly line.
48	Legs well supported & balanced posture:	Are the legs generally well supported and the posture balanced? Is body weight evenly (or reasonably) divided between the legs?
49	Anti-fatigue mats:	Are anti-fatigue mats provided.
50	Adjustability:	Indicate whether the chair, floor, or workstation are adjustable. Choose "No" if none are adjustable. Adjustable means "readily adjustable". For example, if tools are required or maintenance must be called for assistance, it is **not** adjustable.
51	Specific ergonomic suggestion/concern:	Indicate ergonomic concerns that you feel may affect this job and/or possible solutions or abatements. For example, "obstruction causes long reach". Do not "go out of your way" to "solve" all ergonomic concerns.
52	"Hardest Task"	The ergonomist identifies the "hardest task" based on the employee's answer to 14
53	Number of tasks:	Simply record the number of tasks as broken down by the ergonomics team.
54	Time between intermittent tasks:	This is the time between tasks for intermittent tasks (tasks not done every cycle). This should be recorded in hours and minutes. For example, for a task done every 15 minutes, enter "15" in the minutes box.
55	"N/A" "Stress N/O" "S/A"	"N/A": the task is deemed not stressful (not applicable), no UECTD/MMH forms for this task. "Stress N/O": the task is stressful, but was not observed (infrequent). "S/A" means same as (virtually identical to) another task (i.e., front/rear tire install).

56	"Per/cycle" "intermittent" "infrequent"	"Per/cycle": this task is performed every cycle. "Intermittent": task is performed at intervals throughout day (i.e., 1/15 min or 1/4 hrs). Use ave. interval time. "Infrequent": task at intervals > 1/day (i.e., 1/week). Write time in white space.
		OSHA Checklist Form
57	Job ID#:	Identifier used to link all forms related to a particular job.
58	Description:	Brief description of the job (e.g., rear tail light assembly).
59	Upper Extremity Risk Factors	This section considers Upper Extremity Risk Factors
60	Identical/similar upper body motions repeated every few sec	The total duration that identical/similar upper body motions repeated every few sec during the work day (CTH).
61	Grip more than 10 pound load	The number of hours that the worker grips or holds a 10 (or more) pound load (CTH).
62	Pinch more than 2 pounds	The number of hours that the worker pinches with 2 (or more) pounds of force (CTH).
63	Neck: twist/bend (> 20 flex, > 5 ext, or 20 side)	The number of hours that the worker's neck is twisted, flexed, extended or bent to the side (CTH).
64	Unsupported arm during fine or precision work	The number of hours the arms are unsupported during fine or precision work (CTH).
65	Elbow above mid-torso (abduction)	The number of hours the elbows are above mid-torso (abduction) (CTH).
66	Rapid forearm rotation/resisting tool rotation	The number of hours that worker rapid rotates the forearm (e.g., driving screws) or resists tool rotation (e.g., uses a nut-runner or hand drill) (CTH).
67	Wrist bend/deviate (> 20 flex, > 30 ext)	The number of hours the wrist is bent or deviated (CTH).

68	Fingers (forceful gripping)	The number of hours the fingers are used for forceful gripping (CTH).
69	Hard/sharp objects press into skin (upper body)	The number of hours hard or sharp objects press into skin (contact stress) on the upper body (CTH).
70	Hard/sharp objects press into skin (lower body)	The number of hours hard or sharp objects press into skin (contact stress) on the lower body (CTH).
71	Localized vibration (hand/arm)	The number of hours the worker is exposed to localized vibration (hand/arm vibration) (CTH).
72	Back and Lower Extremity Risk Factors	This section considers Back and Lower Extremity Risk Factors.
73	Mild forward or side bending of torso (20-45)	The number of hours that the worker's torso is *mildly* (20-45 degrees) flexed forward or laterally flexed (side bending) during the work day (CTH).
74	Severe forward bending of torso (more than 45)	The number of hours that the worker's torso is *severely* (> 45 degrees) flexed forward during the work day (CTH).
75	Backward bending of torso (extension)	The number of hours the employee's torso is extended (backward bending) during the work day (CTH).
76	Twisting torso	The number of hours the employee's torso is twisted (CTH).
77	Repetitive ankle extension/flexion	The number of hours the employee is repetitively extending or flexing the ankle (CTH).
78	Push/Pull Moderate load	The number of hours the employee pushes or pulls a moderate load (force required to push a shopping cart full of apples) (CTH).
79	Push/Pull Heavy load	The number of hours the employee pushes or pulls a heavy load (force required to push a two-drawer, full file cabinet across a carpeted floor) (CTH).

80	Applicable manual material handling?	If the task requires manual material handling, decide how much time is spent lifting or carrying objects. Choose "up to 1 hour/day" (CTH) or "> 1 hour/day" (CTH). Include all lifting and holding time, not just the time that the object is moving.
81	Manual Handling	This section considers Manual Handling operations (lifting, lowering, carrying, etc.).
82	Average lift position: near / middle / far	The average lifting position for the worker throughout the day. Near: 0-4 inches from toes. Middle: 4-10 inches from toes. Far: >10 inches from toes.
83	Average object weight	The average object weight in pounds.
84	Twisting torso during lifting	On any lift during the job, does the employee twist their torso during lifting.
85	Lifting one-handed	On any lift during the job, does the employee lift with one hand.
86	Lift unstable loads	On any lift during the job, does the employee lift unstable loads.
87	Lift between 1 to 5 times per minute	Does the employee lift between 1 and 5 times per minute.
88	Lift 5 or more times per minute	Does the employee lift 5 or more times per minute.
89	Lifts above the shoulder	On any lift during the job, does the employee lift above the shoulder.
90	Carry objects 10 to 30 feet	On any lift during the job, does the employee carry objects 10 to 30 feet.
91	Carry objects greater than 30 feet	On any lift during the job, does the employee carry objects greater than 30 feet.
92	Lift while seated or kneeling	On any lift during the job, does the employee lift while seated or kneeling.
		Upper Extremity Cumulative Trauma Disorder (UECTD) Form
93	Job ID#:	Identifier used to link all forms related to a particular job.
94	Task #:	The task number for the task analyzed using the UECTD form.

95	Description:	Very brief description of task (to help sort if forms are mixed up). Task should already be described on the job form.
96	Left / Right / Both / Together / Right Same as Left	Which hand(s) is the operator using. If just one hand, choose "Left" or "Right". If both hands are working, but performing different tasks, choose "Both". If both hands are performing the same task in the same location, choose "together".
96		If the hands are both working at the same task in different locations, but with the same relative position from the body (like a mirror image of each other), choose "Right same as Left".
98	Left Hand Activity:	Very brief description of what the left hand is doing.
99	Hold / Connect / Motion / Motion w/out force / Other: _____	This classifies the action/manipulation by a particular hand. Motion: motion to move or manipulate an object. Motion without force: an activity with relatively little force, but potentially significant postures (e.g., sign language/signaling).
100	Object Description	This section describes the object acted upon or manipulated.
101	Size: XS / S / M / L / NA	The size of the object. XS: major dimension < 2" (nuts, bolts, etc.); S: 2"-14"; M: 14"-50"; L: >50" (bumpers, doors, etc.)
102	Wt:	Wt: object weight (not necessarily the weight supported by that hand or lifted). The "load weight or force" is question #138.
103	Torso	This section describes the "gross" body position and torso.
104	Upright / Stoop / Squat / Kneel / Seated (Ht:)	The basic posture that the worker has assumed. Describes what the legs are doing. Upright: no bend in the knees. Stoop: little or no knee bend, bent at waist. Squat: "bent knee lift" position. Kneel: one or both knees touching the ground.
104		For seated workers indicate the seat height (the height of the seat pan above the work surface).

105	Extension	Torso Extension means the torso is in extension (hyper-extended, "leaning back" as in overhead reaching behind the body). "St:" total time that the posture is held statically during the task. "Rp:" total times (repetitions) that the back is extended.
106	Flexion: No 1/4 1/2 3/4 1 -- St: / Rp:	Torso position. "No" means torso is neutral or near neutral. "1/4 - 1" describes level of flexion with "1" being bent over 90 degrees (or more) and "1/2" being at 45 degrees. "St" and "Rp" indicate static time and repetitions respectively.
107	Max Flexion: 1/2 3/4 1 -- St: / Rp:	Max flexion refers to the maximum torso deviation that the worker assumes during the task. This applies when the primary static flexion posture differs from the maximum position. When there is no difference, select "no diff".
108	Lateral flex (side bend): No / Middle / Extreme -- L / R -- St: / Rp:	How far the worker bends to the side ("I'm a little teapot" motion). St: total static time. Rp: times the posture is repeated. Indicate left or right tilt direction.
109	Twisting: No / Middle / Extreme -- L / R -- St: / Rp:	How far the worker twists while performing the task. St: total static time. Rp: times the posture is repeated. Indicate left/right.
110	Speed	Observer rating of the particular *task* speed.
111	% Duration Exertion	Observer rating of the % of the *task* cycle time that the operator is exerting themselves or "working".
112	Intensity	Observer rating of the worker's intensity level (based on upper body exertion level) for this *task* . Please refer to Moore table at the end of this document.
113	Right Hand Activity:	Very brief description of what the right hand is doing.

		Job Requirements Form
1	Process Number	The Ford identification number for this job. Include brief verbal job description (i.e., left tail light install).
2	Job ID #:	Identifier used to link all forms related to a particular job.
3	Drot #:	Identifier for a supervision area (daily report of time), somewhat like department.
4	Subject Name:	Hey! This is obvious!
5	Ford ID #:	The Ford Identification number is the last four digits of the employees social security #.
6	Experience:	How much experience the employee has on this particular job (not jobs like it, but this job). Years, months, or weeks. Use the appropriate time frame.
7	Gender:	Enter the employee's gender.
8	Height:	Enter the employee's height in inches. If the employee gives an obviously erroneous height, use your best estimate.
9	Dominant hand:	Is the employee right-handed, left-handed, or ambi-dexterous. If the employee uses both hands equally well for the jobs they perform, mark ambi-dexterous.
10	Informed Consent Form	Mark whether the employee has completed the informed consent paperwork at medical or at the job site. If the IC must be completed at the job site, make sure that the employee gets a signed copy from the ergonomist team before proceeding.
11	Video tape approval	This indicates whether the employee has given approval for video taping. If the employee does not wish to be video taped and is the only employee who has consented to having their job analyzed, complete the job analysis without taping the employee.

12	Job ID #:	Identifier used to link all forms related to a particular job.
13	Date:	The date the data is collected.
14	Facility	The facility visited (number 1-6).
15	Team member numbers:	Identifiers for the ergonomists analyzing the job. Each ergonomist is given a number.
16	Time of day:	Military time of day.
17	Job cycle time:	Cycle time as measured (minutes : seconds) on-site by the team.
17	Cycle time:	How the cycle time was derived. "Timed" indicates that the job was observed and timed. "Calc from prod" indicates that the time was computed from the daily production numbers (used when the line runs in "spurts"). "N/A" no applicable cycle exists.
18	Hours Worked / Day:	Hours that the employee is working per day NOW
18	Typical hours worked/Day	Hours that employees on this job NORMALLY work per day
19	PPE required:	Personal protective equipment that is required for the job
20	Fit	does the PPE fit, particularly the gloves
21	Operator assessment: What's Hardest Part (specific task(s)) of Job?	What does the operator think is the most difficult aspect of this job
22	Operator assessment: What part(s) of your body is most challenged (affected)?	Where does the operator think that this job is affecting his/her body. What part(s) of the body are "worked" hardest. If the operator has no concerns or feels that the job is "easy", choose "none".
23	Job Requirements	These are questions that should be applied to the entire job, not on task-by-task basis.

24	Palm of hand used as hammer:	"Reps/cycle": the number of times / cycle that the palm of the hand is used to strike. "Reps/day": is the total number of times it is used to strike during intermittent tasks (do not include strikes that occur during each cycle).
25	Knee used as hammer/kicker:	"Reps/cycle": the number of times / cycle that the knee is used to strike or push. "Reps/day": is the total number of times it is used to strike during intermittent tasks (do not include strikes that occur during each cycle).
26	Knee used for boosting:	"Reps/cycle": the number of times / cycle that the worker uses their knee for boosting or lifting. "Reps/day": is the total number of times it is used to boost during intermittent tasks (do not include strikes that occur during each cycle).
27	Operator kneeling required:	The number of hours that the worker must kneel during the work shift (CTH).
28	Operator squatting required:	The number of hours that the worker must squat during the work shift (CTH).
29	Operator seated:	The number of hours that the worker is seated during the work shift (CTH).
30	Adequate back support provided for seated work?	Is adequate back support provided for the seated work?
31	Adequate foot support for seated work	Is adequate foot support provided for the seated work?
32	Mainly static (> 1 minute):	Are any of the body parts held in a "mainly" (mostly) static position for > 1 minute? This does not imply completely continuous static posture, but a "mostly" static posture.
33	General Work Environment	This section describes local work place and "environment" for the job
34	Constant monitoring required:	The operator is required to remain continuously vigilant (i.e., watching a computer screen and waiting for a change or inspecting and removing bad parts from a conveyor belt)

35	Tight daily deadlines (quotas):	Operator must produce a fixed quantity of product before the shift can end.
36	Tightly paced work (machine paced):	Little opportunity for operator discretion, must work at a speed dictated by the assembly line.
37	Piece rate:	There is incentive pay for each unit produced (operators are rewarded for working quickly).
38	Whole Body Vibration (vibrating surface):	The number of hours that the worker is exposed to whole body vibration (through chair or floor) during the shift. The number of hours is the cumulative total for the entire work shift, not necessarily consecutive (Cumulative Total Hours, CTH).
39	Source of vibration:	What is producing the whole body vibration.
40	Cold / Hot temperatures.	The number of hours that the worker is exposed to cold and hot temperatures, respectively (CTH). Intended for temperatures that have an "ergonomic impact" or effect (i.e., working in a refrigerated area or near a furnace).
41	Lighting:	The number of hours that the worker is exposed to poor lighting (low levels or harsh levels, CTH).
42	Other environmental concerns:	Simply write in any other environmental factors that may affect the worker.
43	Comments:	Any comments that may assist with the data reduction. Unusual or important data not solicited by the forms in some other way.
44	Standing:	The number of hours that the worker is standing (on their feet / upright) during the work shift (CTH). This is essentially "on feet" time and includes walking.
45	Stationary (no lower body movement):	The number of hours that the worker is standing and cannot freely move or position their legs (legs are "frozen" - cannot shift feet freely) during the work shift (CTH).

46	Sit/stand stool provided:	Is a sit/stand stool provided? Is it used or not used?
47	Walking required:	The number of hours that the worker must walk (CTH). Walking is defined as 2 mph and purposeful (required by job). Walking does not include following a slow moving assembly line.
48	Legs well supported & balanced posture:	Are the legs generally well supported and the posture balanced? Is body weight evenly (or reasonably) divided between the legs?
49	Anti-fatigue mats:	Are anti-fatigue mats provided.
50	Adjustability:	Indicate whether the chair, floor, or workstation are adjustable. Choose "No" if none are adjustable. Adjustable means "readily adjustable". For example, if tools are required or maintenance must be called for assistance, it is **not** adjustable.
51	Specific ergonomic suggestion/concern:	Indicate ergonomic concerns that you feel may affect this job and/or possible solutions or abatements. For example, "obstruction causes long reach". Do not "go out of your way" to "solve" all ergonomic concerns.
52	"Hardest Task"	The ergonomist identifies the "hardest task" based on the employee's answer to 14
53	Number of tasks:	Simply record the number of tasks as broken down by the ergonomics team.
54	Time between intermittent tasks:	This is the time between tasks for intermittent tasks (tasks not done every cycle). This should be recorded in hours and minutes. For example, for a task done every 15 minutes, enter "15" in the minutes box.
55	"N/A" "Stress N/O" "S/A"	"N/A": the task is deemed not stressful (not applicable), no UECTD/MMH forms for this task. "Stress N/O": the task is stressful, but was not observed (infrequent). "S/A" means same as (virtually identical to) another task (i.e., front/rear tire install).

56	"Per/cycle" "intermittent" "infrequent"	"Per/cycle": this task is performed every cycle. "Intermittent": task is performed at intervals throughout day (i.e., 1/15 min or 1/4 hrs). Use ave. interval time. "Infrequent": task at intervals > 1/day (i.e., 1/week). Write time in white space.
		OSHA Checklist Form
57	Job ID#:	Identifier used to link all forms related to a particular job.
58	Description:	Brief description of the job (e.g., rear tail light assembly).
59	Upper Extremity Risk Factors	This section considers Upper Extremity Risk Factors
60	Identical/similar upper body motions repeated every few sec	The total duration that identical/similar upper body motions repeated every few sec during the work day (CTH).
61	Grip more than 10 pound load	The number of hours that the worker grips or holds a 10 (or more) pound load (CTH).
62	Pinch more than 2 pounds	The number of hours that the worker pinches with 2 (or more) pounds of force (CTH).
63	Neck: twist/bend (> 20 flex, > 5 ext, or 20 side)	The number of hours that the worker's neck is twisted, flexed, extended or bent to the side (CTH).
64	Unsupported arm during fine or precision work	The number of hours the arms are unsupported during fine or precision work (CTH).
65	Elbow above mid-torso (abduction)	The number of hours the elbows are above mid-torso (abduction) (CTH).
66	Rapid forearm rotation/resisting tool rotation	The number of hours that worker rapid rotates the forearm (e.g., driving screws) or resists tool rotation (e.g., uses a nut-runner or hand drill) (CTH).
67	Wrist bend/deviate (> 20 flex, > 30 ext)	The number of hours the wrist is bent or deviated (CTH).

68	Fingers (forceful gripping)	The number of hours the fingers are used for forceful gripping (CTH).
69	Hard/sharp objects press into skin (upper body)	The number of hours hard or sharp objects press into skin (contact stress) on the upper body (CTH).
70	Hard/sharp objects press into skin (lower body)	The number of hours hard or sharp objects press into skin (contact stress) on the lower body (CTH).
71	Localized vibration (hand/arm)	The number of hours the worker is exposed to localized vibration (hand/arm vibration) (CTH).
72	Back and Lower Extremity Risk Factors	This section considers Back and Lower Extremity Risk Factors.
73	Mild forward or side bending of torso (20-45)	The number of hours that the worker's torso is *mildly* (20-45 degrees) flexed forward or laterally flexed (side bending) during the work day (CTH).
74	Severe forward bending of torso (more than 45)	The number of hours that the worker's torso is *severely* (> 45 degrees) flexed forward during the work day (CTH).
75	Backward bending of torso (extension)	The number of hours the employee's torso is extended (backward bending) during the work day (CTH).
76	Twisting torso	The number of hours the employee's torso is twisted (CTH).
77	Repetitive ankle extension/flexion	The number of hours the employee is repetitively extending or flexing the ankle (CTH).
78	Push/Pull Moderate load	The number of hours the employee pushes or pulls a moderate load (force required to push a shopping cart full of apples) (CTH).
79	Push/Pull Heavy load	The number of hours the employee pushes or pulls a heavy load (force required to push a two-drawer, full file cabinet across a carpeted floor) (CTH).

80	Applicable manual material handling?	If the task requires manual material handling, decide how much time is spent lifting or carrying objects. Choose "up to 1 hour/day" (CTH) or "> 1 hour/day" (CTH). Include all lifting and holding time, not just the time that the object is moving.
81	Manual Handling	This section considers Manual Handling operations (lifting, lowering, carrying, etc.).
82	Average lift position: near / middle / far	The average lifting position for the worker throughout the day. Near: 0-4 inches from toes. Middle: 4-10 inches from toes. Far: >10 inches from toes.
83	Average object weight	The average object weight in pounds.
84	Twisting torso during lifting	On any lift during the job, does the employee twist their torso during lifting.
85	Lifting one-handed	On any lift during the job, does the employee lift with one hand.
86	Lift unstable loads	On any lift during the job, does the employee lift unstable loads.
87	Lift between 1 to 5 times per minute	Does the employee lift between 1 and 5 times per minute.
88	Lift 5 or more times per minute	Does the employee lift 5 or more times per minute.
89	Lifts above the shoulder	On any lift during the job, does the employee lift above the shoulder.
90	Carry objects 10 to 30 feet	On any lift during the job, does the employee carry objects 10 to 30 feet.
91	Carry objects greater than 30 feet	On any lift during the job, does the employee carry objects greater than 30 feet.
92	Lift while seated or kneeling	On any lift during the job, does the employee lift while seated or kneeling.
		Upper Extremity Cumulative Trauma Disorder (UECTD) Form
93	Job ID#:	Identifier used to link all forms related to a particular job.
94	Task #:	The task number for the task analyzed using the UECTD form.

95	Description:	Very brief description of task (to help sort if forms are mixed up). Task should already be described on the job form.
96	Left / Right / Both / Together / Right Same as Left	Which hand(s) is the operator using. If just one hand, choose "Left" or "Right". If both hands are working, but performing different tasks, choose "Both". If both hands are performing the same task in the same location, choose "together".
96		If the hands are both working at the same task in different locations, but with the same relative position from the body (like a mirror image of each other), choose "Right same as Left".
98	Left Hand Activity:	Very brief description of what the left hand is doing.
99	Hold / Connect / Motion / Motion w/out force / Other: _____	This classifies the action/manipulation by a particular hand. Motion: motion to move or manipulate an object. Motion without force: an activity with relatively little force, but potentially significant postures (e.g., sign language/signaling).
100	Object Description	This section describes the object acted upon or manipulated.
101	Size: XS / S / M / L / NA	The size of the object. XS: major dimension < 2" (nuts, bolts, etc.); S: 2"-14"; M: 14"-50"; L: >50" (bumpers, doors, etc.)
102	Wt:	Wt: object weight (not necessarily the weight supported by that hand or lifted). The "load weight or force" is question #138.
103	Torso	This section describes the "gross" body position and torso.
104	Upright / Stoop / Squat / Kneel / Seated (Ht:)	The basic posture that the worker has assumed. Describes what the legs are doing. Upright: no bend in the knees. Stoop: little or no knee bend, bent at waist. Squat: "bent knee lift" position. Kneel: one or both knees touching the ground.
104		For seated workers indicate the seat height (the height of the seat pan above the work surface).

105	Extension	Torso Extension means the torso is in extension (hyper-extended, "leaning back" as in overhead reaching behind the body). "St:" total time that the posture is held statically during the task. "Rp:" total times (repetitions) that the back is extended.
106	Flexion: No 1/4 1/2 3/4 1 -- St: / Rp:	Torso position. "No" means torso is neutral or near neutral. "1/4 - 1" describes level of flexion with "1" being bent over 90 degrees (or more) and "1/2" being at 45 degrees. "St" and "Rp" indicate static time and repetitions respectively.
107	Max Flexion: 1/2 3/4 1 -- St: / Rp:	Max flexion refers to the maximum torso deviation that the worker assumes during the task. This applies when the primary static flexion posture differs from the maximum position. When there is no difference, select "no diff".
108	Lateral flex (side bend): No / Middle / Extreme -- L / R -- St: / Rp:	How far the worker bends to the side ("I'm a little teapot" motion). St: total static time. Rp: times the posture is repeated. Indicate left or right tilt direction.
109	Twisting: No / Middle / Extreme -- L / R -- St: / Rp:	How far the worker twists while performing the task. St: total static time. Rp: times the posture is repeated. Indicate left/right.
110	Speed	Observer rating of the particular *task* speed.
111	% Duration Exertion	Observer rating of the % of the *task* cycle time that the operator is exerting themselves or "working".
112	Intensity	Observer rating of the worker's intensity level (based on upper body exertion level) for this *task* . Please refer to Moore table at the end of this document.
113	Right Hand Activity:	Very brief description of what the right hand is doing.

114	Hold / Connect / Motion / Motion w/out force / Other: _____	This classifies the action/manipulation by a particular hand. Motion: motion to move or manipulate an object. Motion without force: an activity with relatively little force, but potentially significant postures (e.g., sign language/signaling).
115	Object Description	This section describes the object acted upon or manipulated.
116	Size: XS / S / M / L / NA	The size of the object. XS: major dimension < 2" (nuts, bolts, etc.); S: 2"-14"; M: 14"-50"; L: >50" (bumpers, doors, etc.)
117	Wt:	Wt: object weight (not necessarily the weight supported by that hand or lifted). The "load weight or force" is question #138.
118	Neck	This section describes the head/neck position of the worker.
119	Extension -- St: / Rp:	Neck extension means the neck is in extension ("bent backwards" as if looking at the ceiling directly above). "Middle" and "Extreme" describe the level of neck flexion present. St: total static time. Rp: times the posture is repeated.
120	Flexion: No / Middle / Extreme -- St: / Rp:	Neck flexion position. "No" means neck is neutral or near neutral. "Middle" and "Extreme" describe the level of neck flexion present. St: total static time. Rp: times the posture is repeated.
121	Max Flexion: -- St: / Rp:	This question need only be answered when the primary static flexion posture differs from the maximum position. When there is no difference, select "no diff".
122	Side bending: No -- L / R -- St: / Rp:	Indicate whether the neck is "side bending" ("holding a phone" motion) left or right. St: total static time. Rp: times the posture is repeated.
123	Twisting: No / Middle / Extreme -- L / R -- St: / Rp:	Indicate whether the neck is twisting left or right. St: total static time. Rp: times the posture is repeated.
124	Job ID#:	Identifier used to link all forms related to a particular job.
125	Task #:	The task number for the task analyzed using the UECTD form.

126	Left Hand and Arm	Describes the position and posture of the left upper extremity.
127	Object Position	This section describes where the object (or work interface) is with respect to the worker.
128	Horizontal distance / Vertical distance	The horizontal distance in inches from the worker's **shoulder** to the object/interface. The vertical distance in inches from the floor to the object/interface.
129	Lateral Zone (from sagittal): front / side / rear -- L / R	The position of the object/interface with respect to the sagittal plane. Front includes from center + or - 45 degrees. Side includes from 45-90 degrees. Rear includes anything greater than 90 degrees from center (behind the body). Indicate left/right.
129		"Left" and "right" can also be used to modify the description of "front". For example, "front" and "right" means that the object/interface is more to the right side than directly in front of the worker (but not > 45 degrees).
130	Interface	This section describes the coupling and grip between the worker and the work piece.
131	Object surface condition: good / poor	Poor surface condition is oily, hot, or slippery. Good is favorable to manipulation.
132	Grip: Wrap / hook / contact / oblique / medial / pinch / press	Type of grip used by the worker. Wrap: power grip (hammer); hook: wrap without thumb (hands under a box); contact: open hand push; medial: wrap with ulnar deviation (knife); oblique: medial with thumb on handle; press: thumb or finger press (button)
133	Grip/Pinch/Press: St: / Rp	Grip/pinch/press: St: total amount of time posture is maintained statically. -- Rp: number of times the posture is repeated.

134	Grip/Pinch/Press: Low / Mod / Near Max - Mtch / Meas	Grip/pinch/press force: Low, moderate, or near max. This is a function of posture. Therefore, what might be a "low" force for a "power grip" might be "near max" for a "pinch grip". -- Mtch: matched force (psychophysical estimate) -- Meas: force measured
135	Forceful tool kick/impact or torque: No / Low / High	Forceful kick or impact is "low" when hand movement is noticeable and "high" when hand movement is significant.
136	Vibration (hand/arm): No / Low / High -- T:	Vibration is "low" when hand movement is detectable (nut runner or drill) and "high" when hand is visibly shaking (buffer). T: enter the approximate time of the vibration exposure during this task.
137	Vibration source:	What is producing the hand-arm vibration.
138	Load wt/Force -- T	The load or weight in pounds. Fill in time (seconds) when continued exertion is present. If the force or load is not significant, as with "motion without force" activities, leave this item blank (do not "estimate" at 1 lb, unless it is 1 lb!).
139	Hand / Wrist / Lower Arm / Elbow	This section includes the postures of the lower arm, wrist, and hand.
140	Finger Motion	Indicates level of finger motions used during the task/activity. "No/low": no significant finger motions (motions are near neutral, slow, or otherwise not significant). "Moderate" and "Rapid" describe "finger intensive" tasks (Vegas black jack dealer).
141	Flexion: No / Middle / Extreme St: / Rp:	Wrist flexion. "No" flexion refers to a neutral or nearly neutral wrist (this does not mean "perfectly" neutral). St: total amount of time that the posture is maintained statically. Rp: number of times the posture is repeated.

Appendix [6]

Abbreviations for Psychosocial and Psychological Risk Factors

Question Items		Direction of Scale	Abbreviation
Psychosocial Questions			
Q. 1)	My job requires that I learn new things	Strongly Disagree - Strongly Agree	*Requires learning new things*
Q. 2)	My job involves a lot of repetitive work	Strongly Disagree - Strongly Agree	*Involves repetitive work*
Q. 3)	My job requires me to be creative	Strongly Disagree - Strongly Agree	*Requires to be creative*
Q. 4)	My job requires a high level of skill	Strongly Disagree - Strongly Agree	*Requires high skill*
Q. 5)	On my job, I have very little freedom to decide how I do my work	Strongly Disagree - Strongly Agree	*Little freedom*
Q. 6)	I get to do a variety of different things on my job	Strongly Disagree - Strongly Agree	*Requires learning variety of things*
Q. 7)	I have a lot to say on what happens on my job	Strongly Disagree - Strongly Agree	*I have say*
Q. 8)	My job requires working very fast	Strongly Disagree - Strongly Agree	*Requires working fast*
Q. 9)	My jop requires working very hard	Strongly Disagree - Strongly Agree	*Requires working hard*
Q. 10)	I am not asked to do an excessive amount of work	Strongly Disagree - Strongly Agree	*No excessive work*
Q. 11)	I have enough time to get the job done	Strongly Disagree - Strongly Agree	*I have enough time*
Q. 12)	My job is very hectic	Strongly Disagree - Strongly Agree	*Job is Hectic*
Q. 13)	I can take a break when I want to	Strongly Disagree - Strongly Agree	*Can take a break*
Q. 14)	My supervisor is willing to listen to my work-related problems	Strongly Disagree - Strongly Agree	*Supervisor support available*
Psychological (Job Satisfaction Questions)			
Q. 15)	All in all, how satisfied are you with your job?	Not at all - Very	*Jsat-Satisfied with job*
Q. 16)	How strongly would you recommend your job to someone else?	Not at all - Very	*Jsat-Will recommend this job*
Q. 17)	If you were looking for a new job, how likely is it that you would decide to take this job again?	Not at all - Very	*Jsat-Will take this job again*

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