THESIS

MUSCULOSKELETAL DISORDER SYMPTOM PREVALENCE AMONG CONSTRUCTION WORKERS

Submitted by

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ABSTRACT

MUSCULOSKELETAL DISORDER SYMPTOM PREVALENCE

AMONG CONSTRUCTION WORKERS

Introduction: Musculoskeletal disorder (MSD) symptoms among construction workers have direct impact on their work ability and quality of life. Understanding self-reported MSD symptoms and their association with work tasks may assist in the identification of interventions to reduce their occurrence. The purpose of this descriptive study was to assess MSD symptom prevalence and job factors that may be associated with symptoms among a sample of 104 construction workers (plumbers and pipefitters) in the San Jose region of California. **Methods:** A self-administered survey, which was used with several other cohorts (including within construction trades) by a variety of investigators, was distributed to 104 plumbers and pipefitters at a local union meeting. The survey assessed demographic characteristics, work-related MSD symptom history in the previous 12-months and job factors which may contribute to MSD symptoms. **Results**: The mean age of the participating workers was 48. The top four body regions reported to have MSD symptoms were the low back, the shoulders, the neck, and the knees. Low back pain was associated with the job factor bending or twisting the back in an awkward way. Shoulder pain was associated with reaching or working overhead or away from the body. Neck pain was associated with working in cramped or awkward positions. **Significance:** Based on these analyses, a prioritization of resources that focus on the anatomical areas most likely to be injured as well as the job factors that contribute to the MSD symptoms in specific construction work may assist in injury prevention.

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Chapter 1 - Introduction

Occupational musculoskeletal disorders (MSDs) are common issue in the U.S. workforce that result in lost or restricted work time (Wang et al., 2016). Construction workers have a relatively high rate of MSDs due to the physical nature of the work tasks performed by trades people (Wang et al., 2016). These disorders often have a direct impact on an employees' quality of work life as well as home life (Valsangkar et al., 2012). To reduce the prevalence of work-related MSDs in the construction industry, it is important to understand the distribution of MSDs by body region. Understanding the specific job tasks that may be associated with the MSD symptoms would also be beneficial. The purpose of this study was to assess the 12-month period prevalence of MSD symptoms among a cohort of construction workers (plumbers and pipefitters), and to assess the job factors, which may be associated with MSD symptoms. Self-reported MSD symptoms and job factors were assessed with a validated questionnaire, which was employed in a variety of occupational cohorts, including the construction trades (Boschman et al., 2012). The results of the present study may help determine the development of specific MSD symptoms and their contributing job factors among workers in the plumbing and pipefitting trade. The following specific aims were accomplished in this thesis.

Specific Aim 1: Determine the 12-month period prevalence of occupational MSD symptoms in nine anatomical regions among a cohort of construction workers at a plumber/pipefitter union meeting. Specific Aim 2: Determine the most problematic job factors that may contribute to work-related MSD symptoms among this cohort. Specific Aim 3: Quantify the association between MSD symptoms in the most prevalent body regions with selected job factors.

Chapter 2 – Review of Literature

The U.S. construction industry employed nearly 11.4 million people in 2019. (Gallagher, 2022). Construction work is considered one of the most dangerous industries in terms of occupational injury and illness rates (Goldsheyder et al., 2004; Rosecrance et al., 1995; Schwatka et al., 2012, National Safety Council, 2022). Globally, workers in the construction industry are three times more likely to die at work, and two times more likely to suffer work-related injuries compared to all other types of work (Wang et al., 2015). Work-related MSDs are one of the primary causes of non-fatal injuries in the construction industry (Wang et al., 2015). Work-related MSDs are also a major cause of lost or restricted work time in this industry (Wang et al., 2015).

Occupational related MSDs are often defined as disorders of the joints, tendons, muscles, and nerves caused by specific work task variables (Wang et al., 2015). These task variables can include highly repetitive motions, awkward or extreme postures, high exertion levels (especially, when lifting or carrying), and whole-body vibration (Wang et al., 2016). According to the International Labor Organization, the costs related to work-related MSDs and work-related ill-health incidents and accidents are equal to 4% of the world's gross domestic product (Ekpenyong & Inyang, 2015).

Surveys and questionnaires are often employed for examining MSD rates among cohorts of workers. A questionnaire developed by Kuorinka et al., (1987) called the "Standardised Nordic" questionnaire was developed to improve MSD evaluation. Although originally developed in 1987, the Standardised Nordic questionnaire is frequently used today for evaluating MSD within specific occupations. Rosecrance et al., (2002) investigated the psychometric

properties of this questionnaire and determined it was reliable and had good temporal stability for both MSD symptoms and worker's perceptions of problematic job factors (Rosecrance et al., 2002). Improving and preventing rates of occupation related MSDs includes analyzing its prevalence in each industry. This has been done in ergonomic research and continues to be investigated and improved.

Merlino et al., (2003) employed an adapted version of the Standardised Nordic questionnaire for determining 12-month period prevalence of MSD symptoms among nearly 1,000 apprentice level construction workers. In the apprentice cohort, the highest prevalence (54.4%) of self-reported MSD symptoms were in the lower back. The second and third highest reported symptoms were in the wrist/hand (42.4%) and knees (38.4%). Merlino et al., (2003) also indicated that more than75% of this cohort reported MSD symptoms in at least one of nine body regions, and 16 participants, or 1.6%, reported MSD symptom prevalence in all nine body regions. Not surprisingly, the high rate of reported low back MSD symptoms resulted in 15% of these workers seeking medical help for this pain sometime in the past 12 months. Additionally, more than 7% reported missing work due to their low back pain in the past 12 months. The prevalence of missed work was also relatively high due to hand/wrist symptoms (3.4%) as well as upper back symptoms (2.8%) among these workers (Merlino et al., 2003).

Merlino et al., (2003) also investigated problematic job factors in their survey of construction apprentices. Problematic job factors were based on construction apprentice's perception of job tasks most likely contributing to their work-related MSD symptoms. The most common reported job factor contributing to MSD symptoms was "working in the same position for long periods" at 49.7%. The second most common problematic job factor was "bending or

twisting the back awkwardly" at 35.8%, and the third most common was "working in an awkward or cramped position" at 32.5% (Merlino et al., 2003).

Rosecrance et al., (1996) used the same two-page questionnaire which was mailed to 1,674 journey level construction workers. The Rosecrance et al., 1996 study had a 40.4% response rate, encompassing 677 completed questionnaires. Only questionnaires provided by active working plumbers and pipefitters were analyzed which resulted in 526 questionnaires. These workers were 43 years old on average with approximately 20 years of experience in the trade. Rosecrance and colleagues (1996) reported that 45% of respondents had low back MSD symptoms, 30% had wrist/hand symptoms, 29% had upper back symptoms, and 25% had neck symptoms. The low back symptoms among these workers resulted in a 2.8% missing work, and a 2.9% needing to see a physician for their condition(s). The specific job factors that participants indicated were the most likely related to their symptoms included "bending or twisting the back in an awkward way", "working in the same position for long periods of time", and "working in awkward or cramped positions" (Rosecrance et al., 1996). This study's findings demonstrated that in the previous year 88.4% of participants experienced MSD symptoms in at least one anatomical region.

A questionnaire similar to the one used by the Rosecrance et al. (1996) was used by Goldsheyder et al., (2004) to assess the job-related MSD symptoms among cement and concrete workers. Surveys were completed by 110 participants, a 55% response rate. They determined that many of these cement and concrete workers participated in a variety of job categories and had worked in this field for less than 10 years (Goldsheyder et al., 2004). The investigators reported that approximately 77% of the concrete workers indicated at least one MSD symptom in the prior 12 months. Low back pain was the most reported MSD symptom at 66% (Goldsheyder

et al., 2004). Due to the prevalent low back pain, 21% of this cohort visited a physician for medical help, and 15% were absent from work because of these symptoms (Goldsheyder et al., 2004). The second most common anatomical area with MSD symptoms was the shoulder, followed by the neck. Due to these shoulder symptoms, 18% sought medical help, and 12% missed work as a result (Goldsheyder et al., 2004).

Goldsheyder et al., (2004) also reported that of all the 15 jobs tasks listed on the survey, "continuing to work when in pain" was the most problematic (Goldsheyder et al., 2004). More than 50% of participants reported continuing to work when in pain as being a moderate problem in their trade, and 36% reported it as being a major problem (Goldsheyder et al., 2004). Another common problematic job-factor considered a major problem was "bending or twisting your back in an awkward way," which was reported by 33.7% of respondents, and 41% reported this as a minor to moderate problem (Goldsheyder et al., 2004). Other work factors among these concrete workers considered problematic in their contribution to MSD symptoms include physical job demands, manual materials handling, physical demand of equipment and tool use, awkward working positions, over-exertion/force, repetitive motion, and this work being fast paced. Goldsheyder et al. (2004) reported a clear lack of safety training and personal protective equipment availability on these job sites which contributed to the rate of MSDs.

Boschman et al, (2012) also used a questionnaire to determine self-reported MSD symptoms among construction workers, specifically bricklayers and supervisors. The authors of this research article were attempting to found differences in MSD prevalence among bricklayers versus supervisors. The survey results indicated that 67% of bricklayers reported one or more MSD symptom(s) that had been an issue in the previous 6 months (Boschman et al., 2012). Among bricklayers, the most common reported area with MSD symptoms were the back at 42%,

the knee at 27%, and the shoulder or upper arm at 24% (Boschman et al., 2012). Among the construction supervisors more than half reported one or more MSD symptom(s) in the last six months (Boschman et al. 2012). These construction supervisors had a lower prevalence of MSD symptoms, but in similar body regions. The back was also the most common at 30%, the shoulder and upper arm at 17%, and the knees and neck at 15% each (Boschman et al., 2012).

Boschman et al. (2012) did a follow-up questionnaires after one year. The researchers used the identical symptom survey as the original and reported that the most recurrent MSD symptoms among bricklayers were in the shoulder and upper arm, knee/upper leg, neck, and back (Boschman et al., 2012). Of the bricklayers who reported back pain in the first questionnaire, 22% said the symptoms were worse a year later. Among all participating bricklayers, 50% reported worsened upper leg and knee symptoms (Boschman et al., 2012). Of the job factors identified that related to these MSD symptoms among the bricklayers, "working with a bent back", was the most common at 72%, "carrying and lifting" was reported by 64%, and "working with arms above shoulder height" was reported by 59% of participants (Boschman et al., 2012).

Construction work is incredibly varied. The kinds of job tasks and how they impact the workers body is entirely dependent on the work tasks performed. Plumbers and pipe fitters are no different. They require specific ergonomic evaluation and remediation based upon the MSD symptoms more likely to occur due to the kind of work. It was found in the literature that plumbers and pipe fitters are more prone to knee issues (Merlino et al., 2003). This is likely related to working in awkward positions for extended periods of time, particularly when bent on knees to reach lower work locations. The Bureau of Labor Statistics categorizes plumbers,

pipefitters, and steamfitters into the same group (Bureau of Labor Statistics, 2022). However, plumbing, pipefitting, and steamfitting are quite distinct kinds of work.

The New England Institute of Technology defines pipefitting work as requiring thorough welding experience (NEIT, 2022). In contrast, plumbing does not require welding skills, but does require more ability to work in cramped spaces (NEIT, 2022). Based on their description, it is also expected for pipefitters to have thorough trenching and shoring knowledge to better fit pipes above or below ground (NEIT, 2022). In the US there are separate licenses for pipefitting work and plumbing work (NEIT, 2022). A plumbing certification requires passing an exam, while pipefitting requires at least 4,000 to 6,000 hours (about 8 months) of work experience (NEIT, 2022). Additionally, pipefitting certifications require a thorough understanding of the American Society of Mechanical Engineers (ASME) codes for boilers, pneumatics, and pressure valves in tandem with 200-350 hours of ASME training (NEIT, 2022). Some states also require Occupational Safety and Health Administration (OSHA) course completion (NEIT, 2022). Certain states also require a state-specific license in addition to certification for pipefitting (NEIT 2022). Steamfitters are like pipefitters; except they specialize in high-pressure flows of liquids and gases.

As shown plumbing and pipe fitting are distinct kinds of work, requiring diverse levels of education and skill sets. However, as they are categorized together by the Bureau of Labor Statistics, this research will do the same. Though plumbing and pipefitting likely have differences in MSD occurrences between one another, MSD symptoms and job factors are similar enough to group them together and obtain data for effective ergonomic interventions. Though it would be prudent for these trades to eventually be evaluated separately, for now they will be viewed as similar enough to group together. As ergonomic interventions advance and

becomes more typical, it is likely every kind of trade will be evaluated separately based on common MSD symptoms and problematic job factors.

As indicated in the review of literature, construction workers have a high rate of work-related MSD symptoms. The reviewed articles also report numerous problematic job factors, some of which may be associated with reported MSDs. Unfortunately, very few of the studies that assessed both MSD symptom prevalence and problematic job factors have determined the association between them. Each construction trade has its specific set of MSD risks and needs to be individually evaluated for targeted ergonomic interventions. Knowing the strength of association between MSD symptom prevalence and problematic job factors among specific fields of construction work is necessary for enhanced ergonomic evaluation and targeted interventions. Thus, the present study's findings pursued the follow specific aims in a cohort of plumbers and pipefitters:

Specific Aim 1 (SA1): To assess the 12-month period prevalence of MSD symptoms within the nine anatomical body regions among this cohort of plumbers and pipefitters.

Specific Aim 2 (SA2): To determine the most problematic job factors that may contribute to work-related MSD symptoms among this cohort.

Specific Aim 3 (SA3): To quantify the association between MSD symptoms in the most prevalent body regions with selected job factors.

Chapter 3 - Methods

The cohort used in this study was comprised of unionized construction workers in the San Jose region of California. The workers were attending a monthly union meeting at the time the data was collected. A self-administered survey, which was used with several other construction cohorts by a variety of investigators (Rosecrance et al., 1996; Bork et al., 1996; Merlino et al., 2003; Goldsheyder et al., 2004), was distributed to these 104 plumbers and pipefitters.

The survey had three sections. The first section consisted of demographic questions regarding type of trade, years in trade, yearly working time, apprentice training, working status, handedness, gender, age, height, weight, and ethnicity (Rosecrance et al., 1996). Ethnicity included the options of "Caucasian," "Hispanic," "African American," "Asian or Pacific Islander," "American Indian or Alaskan Native," as well as "Other."

The second section of this survey was a modification of the Standardized Nordic Questionnaire (Kuorinka et al., 1987) which refers to MSD symptoms in nine specific body regions. This section contained questions specifically about the prevalence of work-related body aches, pains, or discomforts in each anatomical region. If the respondent indicated a "yes" in the symptom category, they were asked if the MSD symptoms led to time off work and / or a visit to a health care provider. The third section of the questionnaire included a list of "problematic job factors" that could contribute to work-related MSD symptoms (Rosecrance et al., 1996).

Specific Aim 1

The first specific aim was to assess the 12-month period prevalence of MSD symptoms within the nine anatomical body regions among this cohort of plumbers and pipefitters. Data collected from the MSD Symptom questionnaire was checked for valid data entry in the Microsoft Excel spreadsheet and organized as appropriate prior to the data analysis. For

example, one participant could have data missing for only certain responses and not others. The 12-month period prevalence rate for each of the nine body regions was determined by dividing "yes" responses (numerator) by the total number of participants (denominator). In addition, the percentage of participants who reported needing to miss work or seek medical help within each body region with MSD symptoms was established.

Specific Aim 2

The second specific aim was to determine the most problematic job factors that may contribute to work-related MSD symptoms among this cohort.. Thus, the second section of the questionnaire focused on a set of 15 job factors that could contribute to work-related MSD symptoms. The job factors portion of the survey utilized a 0–10-point scale. This was for each participant to rate their perception of how problematic each job factor could be at contributing to their MSD symptoms. The 15 job factors listed in the questionnaire include:

1. Performing the same task over and over (abbreviated as "same task").
2. Working very fast for short periods (lifting, grasping, pulling, etc.) (abbreviated as "very fast for short").
3. Having to handle or grasp small objects (abbreviated as "handle or grasp").
4. Insufficient breaks or pauses during the workday (abbreviated as "not enough breaks").
5. Working in awkward or cramped positions (abbreviated as "awkward or cramped").
6. Working in the same position for long periods (standing, bent over, sitting, kneeling, etc.) (abbreviated as "same position").
7. Bending or twisting your back in an awkward way (abbreviated as "bending or twisting").
8. Working near or at your physical limits (abbreviated as "physical limits").

9. Reaching or working over your head or away from your body (abbreviated as "overhead or away from body").

10. Hot, cold, humid, wet conditions (abbreviated as "inclement weather").

11. Continuing to work when injured or hurt (abbreviated as "working when hurt").

12. Carrying, lifting, or moving heavy materials or equipment (abbreviated as "heavy loads").

13. Work scheduling (overtime, length of workday) (abbreviated as "scheduling").

14. Using tools (design, weight, vibration, etc.) (abbreviated as "tools").

15. Training on how to do the job (abbreviated as "training").

Based on a 0-10 scale, a score of 0-1 was considered as no problem, 2-7 as a minimal to moderate problem, and 8-10 as a major problem (Rosecrance et al., 1996). Percentiles and means were developed for each job factor as appropriate for a descriptive analysis of SA2 results. However, for SA3, dichotomization of the problematic job factor score as 0-5 representing no to minor problems and 6-10 as moderate to major problems was necessary. A dichotomous problematic job score allowed the investigation of the strength of associations between MSD symptoms and problematic job factors and compared to other published studies (Merlino, et al., 2003).

Specific Aim 3

The third specific aim was to quantify the association between MSD symptoms in the most prevalent body regions with selected job factors. A 2 x 2 table was used to calculate the strength of association with an odds ratio (OR) and 95% confidence interval. The "Yes" and "No" responses to specific body region with MSD symptoms was evaluated as Cases and Controls, respectively. The job factor score was interpreted as "Yes" problematic if the score

ranged from 6-10 (moderate to major problem) and "Not" problematic if the score is less than 5 (no to minimal problem). The formula used for calculating the OR was OR= (a/c) / (b/d), this is the ratio of the event happening to the event not happening (Figure 1). The 95% confidence interval for the OR, and the significance level (p value) was calculated using Microsoft Excel.

Odds ratios were only determined for the anatomical regions with the four most prevalent self-reported MSD symptoms and corresponding problematic job factors deduced. The decisions on which job factors were tested in the calculation of associations were based on ergonomic principles and literature suggesting significant associations. These resulting 2x2 tables are shown in Appendix A of this paper.

Odds Ratio: Body Region with MSD Symptom & Job Factor #	MSD Symptoms?	
Problematic Job Factor?	Yes	No
Yes	A	B
No	C	D

Figure 1. Two by two table for calculating the odds ratio for the present study.

Chapter 4 - Results

This sample of convenience for the present study consisted of 104 unionized plumbers and pipefitters, of which 89 participated. This represented an 85.6% response rate. A summary table of the age, height, weight, BMI, and years worked in current job are shown in Table 1, General Demographic Data. The mean age of this cohort was 47.7 years. The mean body mass index of this cohort was 29.3. The average time worked at their current job was 15 years.

Table 1. General Demographic Data

	Mean	SD
Age	47.7 years	8.2
Height	70.2 inches	3
Weight	205.9 pounds	36.3
BMI	29.3	4.7
Years Worked at Current Job	15	10.3

This cohort included individuals with multiple job titles. This variety of jobs can be categorized into welders, plumbers, pipefitters, steamfitters, HVAC related work, management/foreman, and other. Though there seems to be variation in these job titles, all of the participants were from a plumbing and pipefitting union meeting. The percentage of these job types are shown in Table 2. Of the 83 participants who indicated their current job title, 23 identified as plumbers, 14 as pipefitters, and seven as steamfitters. Additionally, four identified as welders, 11 as being in HVAC related fields, 13 as management/foreman, and 11 as other. The 11 that identified as other included service technician, construction, computer technician, refrigeration fitting, teaching, building inspector, training, and estimator. This cohort includes 53% plumbers, pipefitters, and steamfitters.

Table 2. Job Titles in Participant Population

Job Title	% of Participant Population
Welder	4.8
Plumber	27.7
Pipefitter	16.9
Steamfitter	8.4
HVAC Related	13.3
Management/Foreman	15.7
Other	13.3

The youngest participant in this cohort was 29 years and the oldest is 65 years. The mean age of this cohort was 47.7 years with a standard deviation of 8.2 years. Figure 2 displays the frequency distribution of the ages within this cohort.

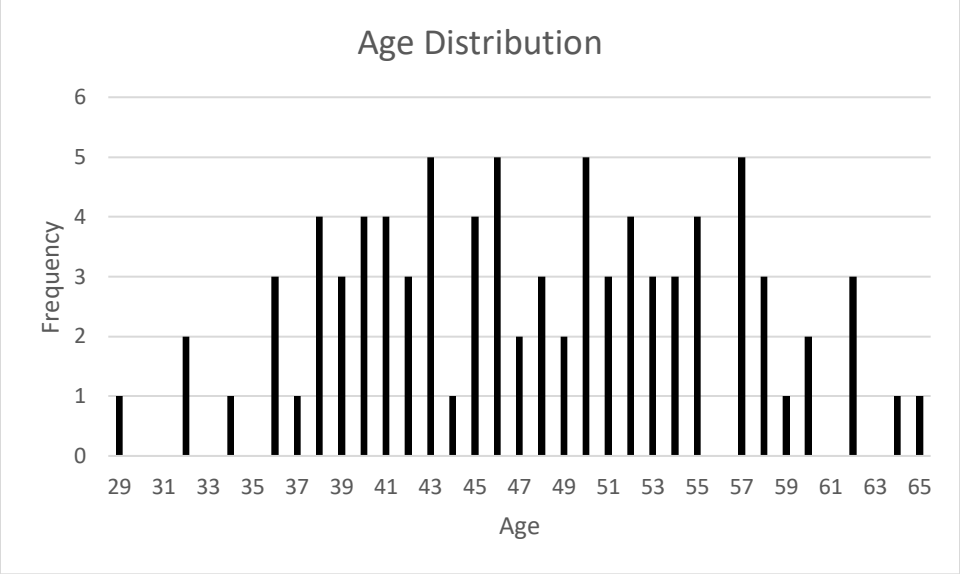

Figure 2. Age Distribution. Frequency distribution of the participant ages in this cohort of workers.

The racial/ethnic demographic data from this cohort were taken from the section of the survey that asks, “Which of these groups best describe your racial/ethnic background?”. It then offers the choices “Caucasian,” “Hispanic,” “African American,” “Asian or Pacific Islander,” “American Indian or Alaskan Native,” and “Other” as options to choose from. The cohort of participants from this study encompassed 57% Caucasian workers, 23% Hispanic, 4% American

Indian or Alaskan Native, 2% Asian or Pacific Islander, 1% African American, and 2% which reported identifying as “Other”. A pie chart was devised to visualize the ethnic/racial characteristics of the cohort used in this study. This is shown in Figure 3.

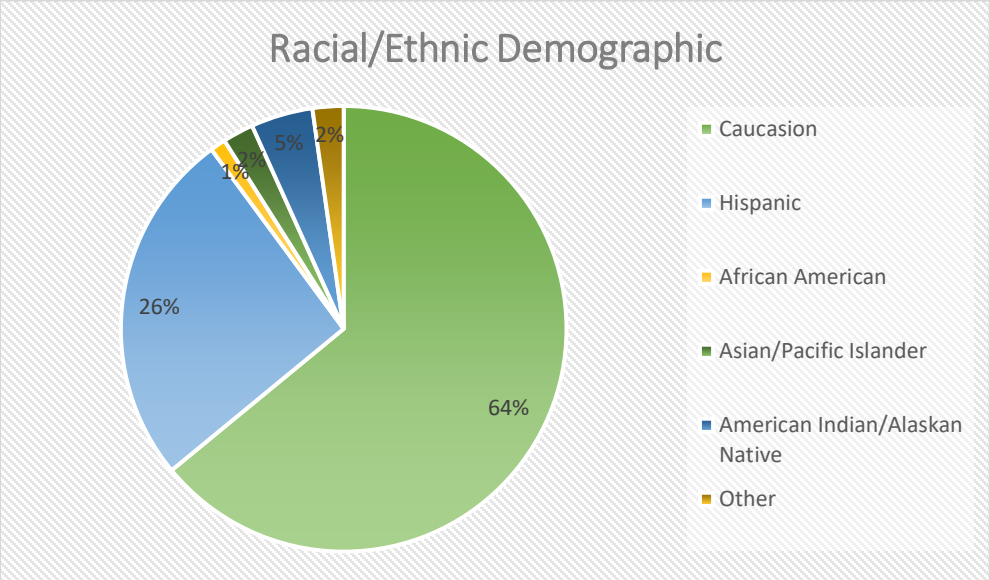

Figure 3. Pie chart of racial/ethnic makeup of this cohort of participating workers.

The reported height and weight for each participant was analyzed to determine body mass index (BMI) distributions in this cohort. Figure 4 is a histogram of this cohort’s BMI distribution. This BMI distribution is positively skewed or skewed to the right. The median, or middle range value of the BMI’s calculated was 28.2. The average BMI found was 29.3, with a standard deviation of 4.7. According to the Centers for Disease Control and Prevention (Centers for Disease Control and Prevention, 2022) a BMI between 18.5 and 24.9 is considered a healthy weight, a BMI of 25 to 29.9 is considered overweight, and a BMI of 30 or higher is classified as obese (Centers for Disease Control and Prevention, 2022). This means the mean BMI in this cohort, 29.3, as well as the median of this cohort, 28.2, are both classified as overweight. It is important to note that an increased BMI has a significant correlation with increased MSD risks (Aghilinejad, et al., 2012).

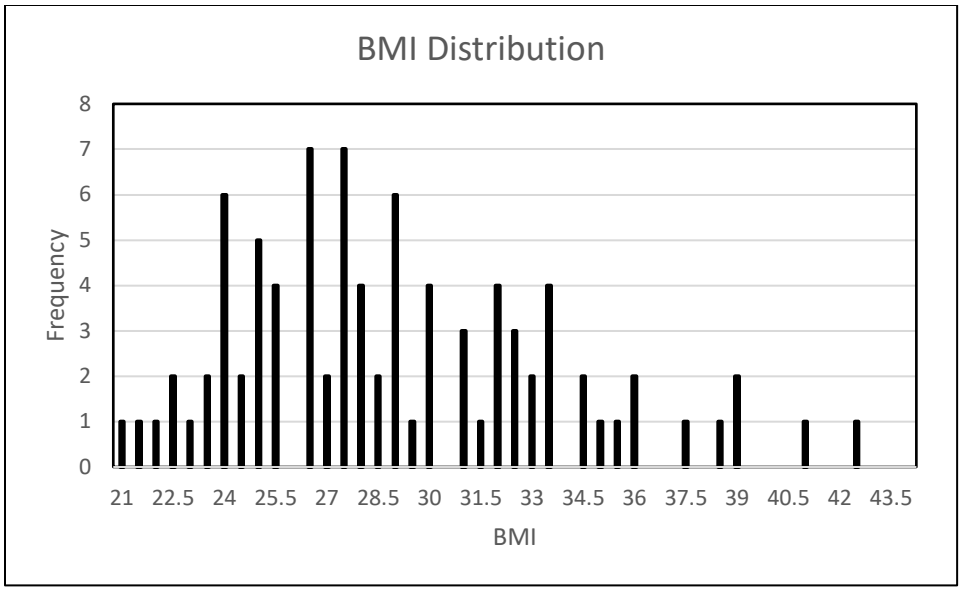

Figure 4. Frequency distribution of the calculated BMI's in this cohort of participating workers.

Specific Aim 1

SA1 was to assess the 12-month period prevalence of MSD symptoms within the nine anatomical body regions among this cohort of plumbers and pipefitters. The Standardized Nordic Questionnaire that was modified for this study asks about 12-month period occurrence of MSD symptoms within nine different body regions. The neck, upper back, low back, shoulder, elbow, wrist, hip, knee, and feet are the nine specified body regions. The 12-month period occurrence of MSD symptoms reported by participants were analyzed by frequency of occurrence. The body region section of the survey was a yes or no question. Within the data set 0 represented no and 1 represented yes. The occurrence rate was determined by dividing the number of "yes" responses by the total number of participants (n=89). The four body regions reported with the highest occurrence of MSD symptoms were the low back at 54.2%, the neck at 43.3%, the knees at 39.1%, and the shoulders at 37.3%. The Hand/Wrist body region fell closely behind shoulders at 36.1% reported as having MSD symptoms. Figure 5 depicts the percentage of reported MSD

symptoms found for each body region in this cohort. The four body regions with the highest MSD symptom prevalence are highlighted in red.

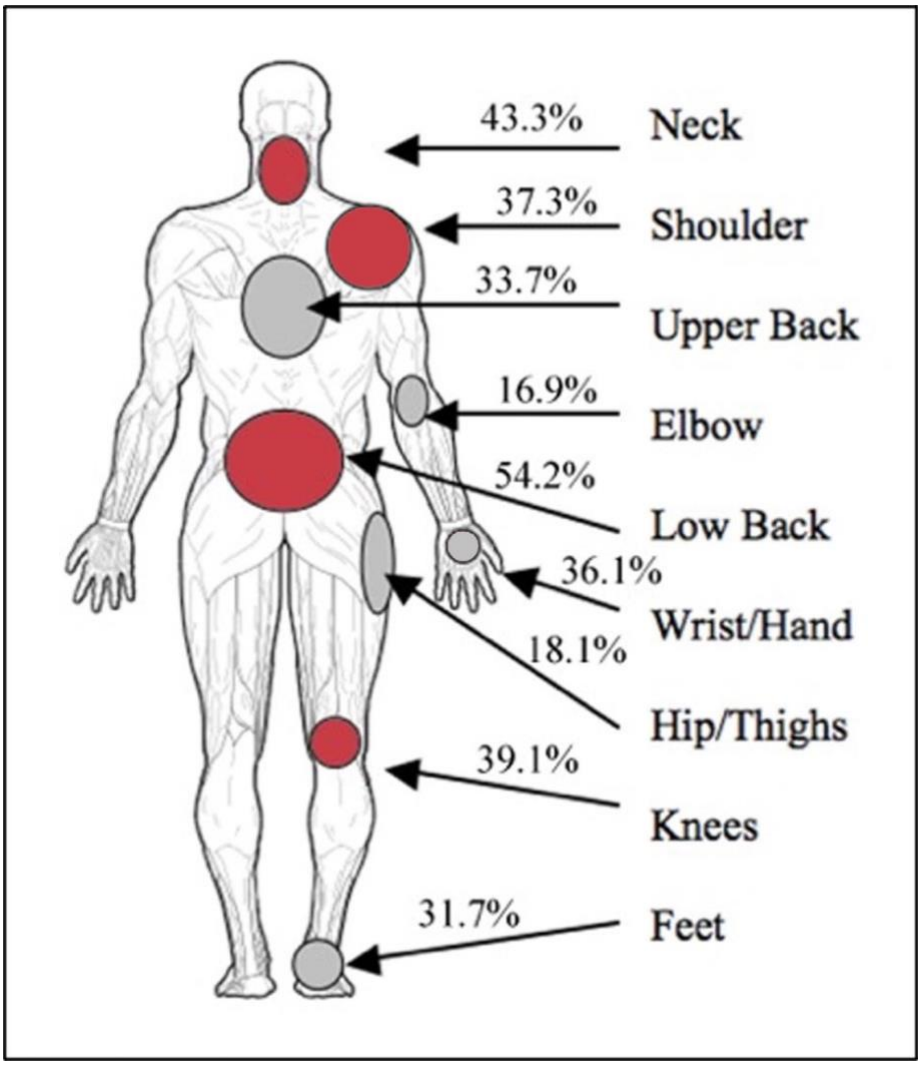

Figure 5. MSD symptom 12-month period prevalence (percent) by body region. Red shading indicates the four body regions with highest prevalence.

The survey also included questions related to if these 12-month period MSD symptoms resulted in lost work time or the need for medical help. The low back also resulted in the highest rate of loss in work time at 6.0% and needing to seek medical help at 26.5%. The percentages of reported body regions with MSD, missed work, and seeking medical help are shown in Table 3.

Table 3. Frequency of Prevalent MSDs in Plumber/Pipefitting trades (N=83)

Anatomic Site	12-month period prevalence had symptoms (%)	12-month period prevalence missed work (%)	12-month period prevalence saw MD (%)
Neck	43.3	3.6	15.7
Upper Back	33.7	3.6	18.1
Low Back	54.2	6.0	26.5
Shoulder	37.3	3.6	13.3
Elbow	16.9	2.4	4.8
Wrist	36.1	4.8	13.3
Hip	18.1	3.6	9.8
Knee	39.1	4.9	15.9
Feet	31.7	2.4	11.0

Specific Aim 2

SA2 was to determine the most problematic job factors that may contribute to work-related MSD symptoms among this cohort. The job factor section of the survey asked participants to rate various job factor's contributions to job-related pain and injury on a scale of 0-10. Specifically, the job factor section of the survey stated the following:

> "This list describes things at work that could contribute to job-related pain and injury. Please indicate, on a scale of 0-10, how much of a problem (if any) each item is for you by circling the appropriate number".

This section of the survey enquired about the workers' perception of job-task specific issues that may be correlated or even causing their MSD symptoms. Each job factor, the mean score for each job factor, and the percentage of participants that scored each job factor no problem, minor to moderate problem, and major problem is displayed in Table 4. The job factor ratings were interpreted as 0-1 representing no problem, 2-7 representing a minor to moderate problem, and 8-10 representing a major problem. Though some of the job factors had a higher percentage of

minor to moderate problem scores (2-7), this study's findings focus on the percentage reported as a major problem.

Job Factor #7 bending or twisting one's back in an awkward way, was the highest percentage reported as being a major problem at 32.5%. The low back was the highest reported body region with MSD issues. The second most reported job factor reported as being a major problem is job factor #6 working in the same position for long periods of time. This job factor was reported as a major problem by 25.3% of participants. The third most reported as being a major problem is job factor #5 working in awkward or cramped positions. This job factor was reported as being a major problem for 24.1% of participants.

Table 4. Job Factor Survey Results (N=89)

Job Factor	Mean Score	% Reported No Problem (0-1)	% Reported Minor - Moderate Problem (2-7)	% Reported Major Problem (8-10)
1. Same Task	3.8	27.7	60.2	12.1
2. Very Fast for Short	2.9	38.6	71.1	9.6
3. Handle or Grasp	2.8	48.2	43.4	8.4
4. Not Enough Breaks	2.4	54.2	41	4.8
5. Awkward or Cramped	4.7	25.3	50.6	24.1
6. Same Position	5.3	12.1	62.7	25.3
7. Bending or Twisting	5.3	18.1	49.4	32.5
8. Physical Limits	3.8	31.3	55.4	13.3
9. Overhead or Away from Body	4.2	31.3	48.2	20.5
10. Inclement Weather	3.4	34.9	54.2	10.8
11. Working When Hurt	4.4	21.7	59.9	19.3
12. Heavy Loads	3.9	25.3	59.0	15.7
13. Scheduling	3.3	26.5	61.7	10.8
14. Tools	3.0	37.4	50.6	8.4
15. Training	2.0	51.8	26.5	4.8

Specific Aim 3

SA3 was to quantify the association between MSD symptoms in the most prevalent body regions with selected job factors. The job factors chosen for each of these body regions with MSD symptoms have been determined based on research experience and anatomical and ergonomic knowledge of the plumbing and pipefitting trades by the authors. For the odds ratio calculation, the exposure was interpreted as the job factor, and the event was the specific body regions with MSD symptoms. For the job factor data, yes responses were interpreted as a response between 6-10 on the 0-10 job factor scale. No responses were interpreted as responses between 0-5 on this 0-10 scale. The job factor data needed to be dichotomized for effective odds ratio calculations. The percentage reported as yes (or as a problem) for each job factor was determined for this specific aim. This is shown in Table 5.

Table 5. Percent Reported as a Problem (score of 6-10) for each Job Factor

Job Factor #	% Reported as a Problem (Score of 6-10)
1. Same Task	31.3
2. Very Fast for Short	20.5
3. Handle or Grasp	20.5
4. Not Enough Breaks	16.9
5. Awkward or Cramped	45.8
6. Same Position	49.4
7. Bending or Twisting	50.6
8. Physical Limits	34.9
9. Overhead or Away from Body	36.1
10. Inclement Weather	27.7
11. Working when Hurt	36.1
12. Heavy Loads	32.5
13. Scheduling	19.5
14. Tools	20.0
15. Training	9.5

Using Microsoft Excel, the crude (unadjusted) odds ratios, 95% confidence interval, and p-value for each exposure and event were determined. These results are shown in Table 6. The 2x2 tables that resulted in these data are shown in the appendices of this paper.

The comparison with the highest resulting odds ratio was the shoulder and job factor #9 reaching or working overhead or away from the body. This comparison had an odds ratio of 4.38 and a p-value of 0.001, which means it was highly statistically significant. This comparison also resulted in a 95% confidence interval of (1.671, 11.502). This interval represents 95% confidence that the value will be somewhere between 1.671 and 11.59. An odds ratio below one implies a protective relationship between the body region and the job factor being compared. The low end of this interval being larger than one implies that this comparison is statistically legitimate. Another comparison with a high odds ratio was the low back and job factor #7 bending or twisting one's back in an awkward way. This comparison had an odds ratio of 4 and a p-value of 0.002. This comparison had a 95% confidence interval of (1.579, 10.135).

The next largest odds ratio was between the shoulders and job factor #12 carrying, lifting, or moving heavy materials or equipment. This association had an odds ratio of 3.78 and a p-value of 0.003. This association had a p-value of 0.003, which was not highly statistically significant than 0.001, but still statistically significant. This comparison had a 95% confidence interval of (1.431, 9.992).

The fourth largest odds ratio was between the comparison of the neck and job factor #5 working in awkward or cramped positions. This comparison had an odds ratio of 3.77 and a p-value of 0.002. The 95% confidence interval resulted with this comparison was (1.511, 9.431).

It is important to note that the confidence intervals for the associations with p-values around or less than 0.001 are the highly statistically significant associations. However, they have

a somewhat wide range of 95% confidence intervals. This likely is due to the small sample size of participants used in this study.

Table 6: Body Region & Job Factor Odds Ratio, 95% CI, Z-Score, and P-Value

MSD Region & JF	Odds Ratio	95% CI	P Value
Low Back & JF#5 Awkward or Cramped	2.212	(0.9, 5.434)	0.041
Low Back & JF#6 Same Position	1.96	(0.805, 4.790)	0.069
Low Back & JF#7 Bending or Twisting	4.00	(1.579, 10.135)	0.002
Low Back & JF#9 Overhead or Away from Body	2.08	(0.815, 5.308)	0.063
Low Back & JF#11 Working when Hurt	1.66	(0.660, 4.182)	0.141
Low Back & JF#12 Heavy Loads	2.56	(0.957, 6.839)	0.031
Knee & JF#4 Not Enough Breaks	2.73	(0.802, 9.311)	0.054
Knee & JF#5 Awkward or Cramped	2.27	(0.905, 5.711)	0.040
Knee & JF#6 Same Position	2.00	(0.801, 4.997)	0.069
Knee &JF#11 Working when Hurt	1.02	(0.403, 2.602)	0.481
Knee & JF#12 Heavy Loads	1.37	(0.529, 3.554)	0.258
Neck & JF#5 Awkward or Cramped	3.77	(1.511, 9.431)	0.002
Neck & JF#6 Same Position	3.53	(1.416, 8.798)	0.003
Neck & JF#7 Bending or Twisting	3.22	(1.298, 7.996)	0.006
Neck & JF#9 Overhead o Away from Body	2.34	(0.938, 5.841)	0.034
Neck & JF#11 Working when Hurt	1.52	(0.618, 3.759)	0.180
Shoulder & JF#1 Same Task	2.93	(1.103, 7.731)	0.016
Shoulder & JF#5 Awkward or Cramped	3.23	(1.269, 8.236)	0.007
Shoulder & JF#6 Same Position	3.73	(1.445, 9.643)	0.003
Shoulder & JF#9 Overhead or Away from Body	4.38	(1.671, 11.502)	0.001
Shoulder & JF#11 Working when Hurt	2.74	(1.075, 6.998)	0.017
Shoulder & JF#12 Heavy Loads	3.78	(1.431, 9.992)	0.004

Chapter 5 - Discussion

Work related MSDs are of large concern in the construction industry. It is important to take into consideration the job type and work tasks when addressing these issues. The goal of the present study was to examine plumbers and pipefitter MSD rates by assessing self-reported previous 12-month MSD symptoms and its relation to specific job factors. The resulting data indicated that the top four body regions with the highest rates of MSD symptoms were the low back, knees, shoulders, and neck. The job factor reported as contributing to MSD symptoms (score of 6-10) the highest were the job factor bending or twisting the back in an awkward way (#7). The second highest reported job factor was working in the same position for long periods (#6). The third highest reported job factor was working in awkward or cramped positions (#5). When assessing job factors reported as a major problem (score of 8-10) the top three reported were these same three job factors, #7, #6, and #5.

The reported 12-month period prevalence of MSD symptoms in these top four body regions are closely associated with specific work tasks. Researchers from the current study found the strongest association with the largest odds ratio was the shoulder body region and the job factor reaching or working overhead or away from the body (#9). This association had an odds ratio of 4.38 and a p-value of 0.001. This association was not surprising due to the involvement of the shoulder when needing to work overhead or away from the body. This odds ratio tells us that the odds of having MSD symptoms in the shoulder body region was 4.38 times more likely when the job required reaching or working overhead or away from the body (#9). In other words, the odds of developing shoulder MSD symptoms went up 338% when the job required working

overhead or away from the body. This p-value (0.001) indicates that this association was highly statistically significant. The 95% confidence interval for this association is (1.671, 11.502). This confidence interval was somewhat wide in range which was likely related to the sample size of this study being small (N=89). All the association made for the shoulder body region are high, all being above 2. However, the remaining p-values (besides the association between the shoulders and job factor #9) are larger. This means these remaining shoulder associations are not as statistically significant as the shoulder and job factor reaching or working overhead or away from the body (#9).

Another statistically significant association was the low back body region and the job factor bending or twisting the back in an awkward way (#7). This association had the second largest odds ratio of 4 and a p-value of 0.002. This association was also not surprising due to the involvement of the back when needing to bend or twist the back while working. This odds ratio tells us that it was 4 times more likely to develop low back MSD symptoms if the work required bending or twisting the back in an awkward way (#7). In other words, the odds of developing MSD symptoms went up 300% if the job required bending or twisting the back awkwardly. This association's p-value was slightly higher than the association between the shoulder and job factor working overhead or away from the body (#7), but still statistically significant. Of all the low back body region associations, the association with job factor #7 was by far the highest. The remaining odds ratios for low back associations are 2.5 and below. The p-values of the remaining associations are larger as well, also indicating lower statistical significance).

The third highest odds ratio in conjunction with a low p-value was the association between the neck and the job factor working in awkward or cramped positions (#5). This was again not a surprising association as often when workers need to work in cramped postures it

puts strain on the neck. This association had an odds ratio of 3.77. This odds ratio means the odds of developing MSD symptoms in the neck was 3.77 times more likely if the job required working in awkward or cramped positions. In other words, the odds of developing neck MSD symptoms went up 277% if the work required working in an awkward or cramped position. This association had a p-value of 0.002. This p-value was again higher than the p-value resulting from the association of the shoulder and working overhead or away from the body. However, like the association between the low back and bending or twisting, it was still highly statistically significant.

The fourth most significant finding was the association between the neck and the job factor working in the same position for long periods of time (#6). Once more this is not surprising as needing to work in the same position for long periods of time can put strain on the neck. This association resulted in an odds ratio of 3.5. This means the odds of developing neck MSD symptoms was 3.5 times more likely if the work required working in the same position for long periods of time. In other words, the odds of developing neck MSD symptoms went up 250% if the work required working in the same position for long periods of time. This odds ratio was also high but had a p-value of 0.003. This p-value was slightly less statistically significant than the association between the neck and job factor working in awkward or cramped positions (#5), which resulted in a p value of 0.002. Every association made for the neck are somewhat high (>2), except for the association between the neck and the job factor continuing to work when injured or hurt (#11) which had an odds ratio of 1.5.

Like the present study, Rosecrance et al. (1996) examined pipefitting trades. There were 526 participants in the Rosecrance et al. (1996) study. They found that the body regions with the highest rates of 12-month period prevalence of MSD symptoms included the low back at 45%,

the wrist/hands at 29.6%, the upper back at 28.7%, and the neck at 24.7% (Rosecrance et al., 1996). The researchers in the current study found the low back reported at 54%, wrist/hands at 36%, upper back at 33.7%, and neck at 43%. The researchers from the Rosecrance et al., (1996) study also found the job factors with the highest percentage reported as a major problem included job factor #7 bending or twisting the back in an awkward way, #6 working in the same position for long periods of time, and #5 working in awkward or cramped positions (Rosecrance et al., 1996). These were the same top three job factors found in the current study. The current study involved a cohort of slightly heavier participants than the cohort used in the Rosecrance et al. (1996) study. This could play a role in why the Rosecrance et al. (1996) results of MSD rates were lower than the current study's results.

Another interesting difference was the researchers from the Rosecrance et al. (1996) study found that only 2.9% of their participants needed to seek out medical help for low back MSD symptoms from the previous 12-months. In the current study, 26.5% of participants reported needing to seek medical help for low back MSD symptoms from the previous 12-months. Additionally, these researchers found only 2.8% of their participants reported missing work due to low back MSD symptoms (Rosecrance et al., 1996). Researchers from the current study found that 6% of the participants reported missing work due to low back MSD symptoms. Researchers from the Rosecrance et al. (1996) study distributed this survey to multiple union meetings, whereas the current study's researchers distributed it to a single union meeting. This could have influence on the diversity of the kinds of workers that participated. This difference in diversity could have influenced the results of both the Rosecrance, et al. (1996) study, as well as the current study.

Researchers from the Goldsheyder et al., (2004) MSD construction study also used a version of this survey for examining the MSD symptom prevalence among cement and concrete workers. Once again, the rate of 12-month period MSD symptoms in the low back were the highest at 66%, higher than the findings from the current study (54.2%). The second highest reported body region they found were the shoulders at 47%, also higher than the current study's findings of 37.3%. The third highest was the neck at 44%, similar to the current study's findings of 43.3%. (Goldsheyder et al., 2004). Researchers from the Goldsheyder et al. (2004) study found 15% of participant report missing work due to low back MSD symptoms in the last year. This was more than the findings from the current study which was 6% who reported missing work due to low back MSD symptoms in the last year. Researchers from the Goldsheyder et al., (2004) article also found 31% of participants report seeking medical help because of low back MSD symptoms in the last year. However, the percentage of participants reporting seeking medical help due to neck MSD symptoms was higher at 36%. Of all the body regions with MSD symptoms in the last year, the highest percent reported causing the need to seek out medical help in the current study was the low back, at 26.5%.

Alternatively, researchers from the Goldsheyder et al., (2004) study found the job factor with the highest percentage reported as a major problem was continuing to work when in pain (35.8%). This was similar to the findings of the current study which was 19.3%. The next highest reported job factor from the results in the Goldhseyder et al. (2004) study were bending or twisting the back in an awkward way at 33.7%, similar to the results from the current study which show this job factor reported at 32.5%. Goldsheyder et al., (2004) found both working in an awkward position and working in hot, cold, humid, wet conditions at 31% reporting as a major problem (Goldsheyder et al., 2004). The current study found that this same job factor was

reported as a major problem by 24.1% of participants. It also found that working in hot, cold, humid, or wet conditions was lower at 10.8%. This difference in the percentage reported of the job factor working in hot, cold, humid, or wet conditions as being a major problem could relate to the Goldsheyder et al. (2004) study being done in New York State, whereas the current survey uses participants from California.

Merlino et al., (2003) researchers used a cohort of 996 apprentice level construction workers with a mean age of around 27 years. These included electricians, sheet metal workers, plumbers, and operating engineers. The cohort used in the Merlino et al., (2003) study was 93.3% male. Almost identical to the current study's findings of 54.2% participants reporting low back MSD symptoms, Merlino et al., (2003) findings showed 54.4% of participants reporting low back MSD symptoms. The current study results showed 43.3% participants reporting neck MSD symptoms, while Merlino et al., (2003) results showed only 31.8% reporting neck MSD symptoms.

The current study's result showed 39.1% of the participants report knee MSD symptoms, very similar to Merlino et al., (2003) findings of 38.4% of their participants reporting knee MSD symptoms. The current study's participants reported higher rates of shoulder MSD symptoms (37.3%) compared to Merlino et al., (2003) participant reporting of shoulder MSD symptoms (27.9%). Merlino et al., (2003) found higher reports of hand/wrist MSD symptoms (42.4%) than the current study (36.1%). The current study's participants also had a much higher rate of reports regarding seeking medical help for low back MSD symptoms (26.5%) compared to Merlino et al., (2003) participants (16.8%). However, Merlino et al., (2003) participants report slightly more missed work time due to low back MSD symptoms (7.3%) than the current study (6%).

Merlino et al., (2003) researchers also found specific job factors were associated with their top three reported body regions. The Merlino et al. (2003) researchers defined job factors as being a problem if they were scored between 5-10. This differs from researchers in the current study who defined a problematic job factor as being scored 6-10. The body regions the Merlino et al. (2003) researchers conducted odds ratios for were the low back, the hand/wrists, and the knee. Merlino et al., (2003) researchers found the crude odds ratio for the low back and the job factor working in the same position for long periods (#6) was 2.9. In other words, they found the odds of developing low back MSD symptoms was 2.9 times higher when the work involved the job factor working in the same position for long periods of time. Merlino et al., (2003) researchers also found that the crude odds ratio between low back and the job factor bending or twisting the back in an awkward way (#7) was 4. In other words, Merlino et al., (2003) researchers found that the odds of developing low back MSD symptoms were 4 times higher when the work involved bending or twisting the back in an awkward way (Merlino et al., 2003).

Merlino et al., (2003) researchers also found crude odds ratios for associations the current study did not investigate. These include the knee and job factor working in hot, cold, humid, and wet conditions (#10), which they found had a crude odds ratio of 2.33 (Merlino et al., 2003). They also did various associations between the body region wrist/hands, as this body region was more highly reported than in the current study. They compared the wrist/hands with the job factor performing the same task over and over (#1) and found a crude odds ratio of 4.53 (Merlino et al., 2003). They compared the wrist/hands with the job factor having to handle or grasp small objects (#3) which resulted in a crude odds ratio of 4.45 (Merlino et al., 2003). They compared the wrist/hands to the job factor working in the same positions for long periods of time (#6) which had a crude odds ratio of 2.71 (Merlino et al., 2003). Lastly, they compared the

wrist/hands to the job factor working near or at one's physical limits (#8) which had a crude odds ratio of 1.78 (Merlino et al., 2003). Merlino et al. (2003) researchers found similar results as the current study's results. However, the cohort used in the Merlino et al., (2003) study was significantly younger with a mean of 27.7 years, as well as thinner with an average BMI of 26.4. This could account for differences in these results.

Limitations

Limitations of this study included the limited sample size and few details on the type of work performed by participants. The present study was cross sectional in design and no causal inferences can be made from the results. The results are also limited to the workers involved in the study. Recall bias regarding MSD symptoms in the last 12 months may have affected the results. Additionally, the job factors analyzed were based on participant perceptions and not actual working conditions.

Chapter 6 - Conclusion

This descriptive study quantified MSD symptoms and contributing job factors among a cohort of plumbers and pipefitters. Plumbers and pipefitters examined in this research project had relatively high prevalence of MSD symptoms in the low back, neck, knee, and shoulder. Each of these body regions with MSDs were shown to be associated with specific job factors. Addressing these job factors may assist in the targeting of interventions to improve working conditions related to occupational safety and ergonomic concerns. The development of training programs to prevent MSDs in the plumbing and pipefitting trades may find the results from the present study as useful baseline. Like previous studies, the present study demonstrated the usefulness of employing a standardized MSD surveys as an effective way to gain insight into specific job factors that can contribute to MSD symptoms. Using self-reported data can be beneficial for greater understanding when it comes to personal issues such as occupational related discomfort and pain as well as perceptions of contributing job factors. .

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Appendix

The following tables (Tables 1-22) are the 2x2 tables used to find the odds ratios for each body region and associating job factor. The percent of participants who reported each category is shown with the count in parenthesis next to it.

Tables A1-A6 ……Low Back & Job Factor 5, 6, 7, 9, 11, and 12

Table A1

Low Back & Job Factor #5	MSD	
Job Factor	Yes	No
Yes	30.9% (25)	16% (13)
No	24.7% (20)	28.4% (23)

Table A2

Low Back & Job Factor #6	MSD	
Job Factor	Yes	No
Yes	30.9% (25)	17.3% (14)
No	24.7% (20)	27.2% (22)

Table A3

Low Back & Job Factor #7	MSD	
Job Factor	Yes	No
Yes	37% (30)	14.8% (12)
No	18.5% (15)	29.6% (24)

Table A4

Low Back & Job Factor #9	MSD	
Job Factor	Yes	No
Yes	24.7% (20)	12.3% (10)
No	30.9% (25)	32.1% (26)

Table A5

Low Back & Job Factor #11	MSD	
Job Factor	Yes	No
Yes	23.5% (19)	13.6% (11)
No	32.1% (26)	30.9% (25)

Table A6

Low Back & Job Factor #12	MSD	
Job Factor	Yes	No
Yes	23.5% (19)	9.9% (8)
No	32.1% (26)	34.6% (28)

Tables A7-A11 ……Knee & Job Factor 4, 5, 6, 11, and 12

Table A7

Knee & Job Factor #4	MSD	
Job Factor	Yes	No
Yes	10.3% (8)	6.4% (5)
No	30.8% (24)	52.6% (41)

Table A8

Knee & Job Factor #5	MSD	
Job Factor	Yes	No
Yes	23.1% (18)	23.1% (18)
No	17.9% (14)	35.9% (28)

Table A9

Knee & Job Factor #6	MSD	
Job Factor	Yes	No
Yes	24.4% (19)	23.1% (18)
No	16.7% (13)	35.9% (28)

Table A10

Knee & Job Factor #11	MSD	
Job Factor	Yes	No
Yes	15.4% (12)	21.8% (17)
No	25.6% (20)	37.2% (29)

Table A11

Knee & Job Factor #12	MSD	
Job Factor	Yes	No
Yes	15.4% (12)	17.9% (14)
No	25.6% (20)	41%(32)

Tables A12-A16……...Neck & Job Factor 5, 6, 7, 9, and 11

Table A12

Neck & Job Factor #5	MSD	
Job Factor	Yes	No
Yes	27.7% (23)	18% (15)
No	15.7% (13)	38.6% (32)

Table A13

Neck & Job Factor #6	MSD	
Job Factor	Yes	No
Yes	28.9% (24)	20.5% (17)
No	14.5% (12)	36.1% (30)

Table A14

Neck & Job Factor #7	MSD	
Job Factor	Yes	No
Yes	28.9% (24)	21.7% (18)
No	14.5% (12)	34.9% (29)

Table A15

Neck & Job Factor #9	MSD	
Job Factor	Yes	No
Yes	20.5% (17)	15.7% (13)
No	22.9% (19)	41% (34)

Table A16

Neck & Job Factor #11	MSD	
Job Factor	Yes	No
Yes	18.1% (15)	18.1% (15)
No	25.3% (21)	38.6% (32)

Tables A17-A22……Shoulder & Job Factor 1, 5, 6, 9, 11, and 12

Table A17

Shoulder & Job Factor #1	MSD	
Job Factor	Yes	No
Yes	17.3% (14)	13.6% (11)
No	21% (17)	48.1% (39)

Table A18

Shoulder & Job Factor #5	MSD	
Job Factor	Yes	No
Yes	24.7% (20)	22.2% (18)
No	13.6% (11)	39.5% (32)

Table A19

Shoulder & Job Factor #6	MSD	
Job Factor	Yes	No
Yes	26% (21)	22.2% (18)
No	12.3% (10)	39.5% (32)

Table A20

Shoulder & Job Factor #9	MSD	
Job Factor	Yes	No
Yes	22.2% (18)	14.8% (12)
No	16% (13)	46.9% (38)

Table A21

Shoulder & Job Factor #11	MSD	
Job Factor	Yes	No
Yes	19.8% (16)	17.2% (14)
No	18.5% (15)	44.4% (36)

Table A22

Shoulder & Job Factor #12	MSD	
Job Factor	Yes	No
Yes	19.8% (16)	13.6% (11)
No	18.5% (15)	48.1% (39)