MUSCULAR SYSTEM - ANATOMY, FUNCTIONS AND INJURIES

# MUSCULOSKELETAL DISEASES

## TYPES, CAUSES AND TREATMENTS

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# MUSCULOSKELETAL DISEASES

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# Contents

# Preface

This book provides an analysis of costs of musculoskeletal disorders of employed individuals. It also discusses the application of differential scanning calorimetry for the diagnosis of musculoskeletal disorders, and the effects of stretching and sensory motor training for older adults with musculoskeletal disorders.

Chapter I – Musculoskeletal Disorders (MSD) are one of the leading classes of health effects and can be caused by various factors, work related and nonwork related. MSD refers to health related problems of the locomotor apparatus, i.e. health problems of the skeleton, ligament, muscles, tendons, joints, nerves and cartilage. Rates of MSD vary by population, their age groups, genders, socioeconomic aspects and other factors. These factors can affect the author's understanding of the prevalence, incidence, and costs of MSD aside from the variability of actual prevalence or incidence rates due to etiologic issues or costs due to illness or injury severity or treatment response and recovery. This chapter focuses on types of MSD of employed individuals, and associated medical costs and demographic factors. The US Bureau of Labor Statistics (BLS) classifies occupational MSD as cases where nature of injury or illness is pinched nerve; herniated disc; meniscus tear; sprains, strains, tears; hernia (traumatic and nontraumatic); pain, swelling, and numbness; carpal or tarsal tunnel syndrome; Raynaud's syndrome or phenomenon; musculoskeletal system and connective tissue diseases and disorders, when the event or exposure leading to the injury or illness is overexertion and bodily reaction, unspecified; overexertion involving outside sources; repetitive motion involving micro tasks; other and multiple exertions or bodily reactions; and rubbed, abraded, or jarred by vibration. The economic burden of occupational MSDs is very high. BLS reports that about 30 percent of all occupational injuries involving days away from work are due to MSDs.

While some studies have focused on economic burden, here the author's concentrate on the costs of assessment and treatment of MSDs. MarketScan databases are used to analyze these medical costs by ICD9 codes for the year 2010. These databases consist of millions of records on medical claims classified by ICD9 codes, different medical cost components and some socioeconomic and demographic variables. The results obtained in this study suggests that the average costs per person among the three body regions (neck, upper back and lower back) of focus in this analysis were found to be highest for upper back in the inpatient data and for lower back in the outpatient data. Approximately half (25 out of 47) ICD-9 codes with the highest average costs per person in the inpatient data consisted of intervertebral disc, spinal stenosis, and spinal curvature codes. Of the outpatient service records examined, 23 out of 50 codes were for intervertebral disc, spinal curvature, and spinal stenosis diagnoses.

Chapter II – Background: Despite of the improved biochemical analyzes and imaging technology, diagnosis of different types of musculoskeletal diseases is still challenging. New methods are needed to improve the diagnostic procedures and help to select the most sufficient treatment. Aims: The purpose of the author's current review was to demonstrate the usefulness of differential scanning calorimetry in the intraoperative diagnosis of musculoskeletal diseases. Materials and methods: Different types of ligaments, connective tissues, joint capsules, arthritic or septic hyaline cartilage were collected intra operatively from pathologic, or healthy human origin. The thermal denaturation of the samples was monitored by a SETARAM Micro DSC-II calorimeter. Results: Here the author's demonstrated a significant difference in the pattern of the thermal denaturation characteristics of the degenerative or inflamed collagen tissue samples, compared with the healthy human connective tissue. The degenerative samples' thermal enthalpy was significantly decreased, while the melting temperature showed an increase. In case of the inflamed samples, the author's found a significant increase in the enthalpy and a decrease of melting temperature. Conclusion: These data suggest that DSC analysis could be a clinically relevant, additional method in the intraoperative diagnosis of different types of musculoskeletal diseases.

Chapter III – The ageing process is responsible per se for a series of morphological and functional alterations of the musculoskeletal system, which can compromise the functional independence of the elderly. It is common the decrease in muscle mass (sarcopenia) and in muscle force (dinapenia). It also occurs increase in the stiffness of the muscle-tendon unit, decrease in fascicle length and in the pennation angle related to the aged. These changes

negatively affect the muscle strength and may also impair the mobility, balance and gait of the older adults. When associated with physical inactivity there is a potentiation of the deleterious effects resulted from aging process, and these situations can be recognized as musculoskeletal diseases. Still, the poor mobility associated with decrease in muscle strength and balance can increase the chances of falls in this population. Thus, to mitigate and/or reverse these changes it has been recommended regular physical activity and//or systematic exercise. A number of different types of exercise have been suggested, among them stretching, neuromotor and balance exercises are emphasized. Stretching exercises, when performed by a period equal to or greater than four weeks with three to four repetitions and duration between 30 and 60 seconds, has proved to be effective not only in improving flexibility and range of motion, but also gait speed, which is related with a lower risk of falls. Among the neuromotor exercises, video game exercise training has been shown to be effective in improving balance, agility and muscular strength, and also in reducing the risk of falls in community elderly. For a specific balance training, it has been recommended that this must be composed by gradual exercise in complexity and support base, starting from simple postures and greater support and developing throughout training; dynamic movements that can alter the center of gravity, recruiting postural muscles; and can also reduce the sensory imput information, for example, perform the same exercise, but with eyes closed. The training should be performed two to three times a week, lasting 20-30 minutes per session. Thus, it is emphasized the importance of exercise for older people, especially regular stretching, balance and neuromotor ones can be adopted to prevent and/or improve flexibility, balance, mobility, comorbidities and musculoskeletal diseases in this population.

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*Chapter I*

# Analysis of Costs of Musculoskeletal Disorders of Employed Individuals

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## Abstract

Musculoskeletal Disorders (MSD) are one of the leading classes of health effects and can be caused by various factors, work related and nonwork related. MSD refers to health related problems of the locomotor apparatus, i.e. health problems of the skeleton, ligament, muscles, tendons, joints, nerves and cartilage. Rates of MSD vary by population, their age groups, genders, socioeconomic aspects and other factors. These factors can affect our understanding of the prevalence, incidence, and costs of MSD aside from the variability of actual prevalence or incidence rates due to etiologic issues or costs due to illness or injury severity or treatment response and recovery.

This chapter focuses on types of MSD of employed individuals, and associated medical costs and demographic factors. The US Bureau of Labor Statistics (BLS) classifies occupational MSD as cases where nature of injury or illness is pinched nerve; herniated disc; meniscus tear;

sprains, strains, tears; hernia (traumatic and nontraumatic); pain, swelling, and numbness; carpal or tarsal tunnel syndrome; Raynaud's syndrome or phenomenon; musculoskeletal system and connective tissue diseases and disorders, when the event or exposure leading to the injury or illness is overexertion and bodily reaction, unspecified; overexertion involving outside sources; repetitive motion involving micro tasks; other and multiple exertions or bodily reactions; and rubbed, abraded, or jarred by vibration

The economic burden of occupational MSDs is very high. BLS reports that about 30 percent of all occupational injuries involving days away from work are due to MSDs. While some studies have focused on economic burden, here we concentrate on the costs of assessment and treatment of MSDs. MarketScan databases are used to analyze these medical costs by ICD9 codes for the year 2010. These databases consist of millions of records on medical claims classified by ICD9 codes, different medical cost components and some socioeconomic and demographic variables.

The results obtained in this study suggests that the average costs per person among the three body regions (neck, upper back and lower back) of focus in this analysis were found to be highest for upper back in the inpatient data and for lower back in the outpatient data. Approximately half (25 out of 47) ICD-9 codes with the highest average costs per person in the inpatient data consisted of intervertebral disc, spinal stenosis, and spinal curvature codes. Of the outpatient service records examined, 23 out of 50 codes were for intervertebral disc, spinal curvature, and spinal stenosis diagnoses.

# Introduction

Musculoskeletal Disorders (MSD) refers to health related problems of the locomotor apparatus. The World Health Organization defines MSD as health problems of the skeleton, ligament, muscles, tendons, joints, nerves and cartilage (Luttman, 2003). The US Bureau of Labor Statistics (BLS) classifies occupational MSD as cases where nature of injury or illness is pinched nerve; herniated disc; meniscus tear; sprains, strains, tears; hernia (traumatic and nontraumatic); pain, swelling, and numbness; carpal or tarsal tunnel syndrome; Raynaud's syndrome or phenomenon; musculoskeletal system and connective tissue diseases and disorders, when the event or exposure leading to the injury or illness is overexertion and bodily reaction, unspecified; overexertion involving outside sources; repetitive motion involving micro tasks; other and multiple exertions or bodily reactions; and rubbed, abraded, or jarred by

vibration. MSD can be classified by International Statistical Classification of Diseases, ninth revision (ICD-9) codes, and also by the nature and anatomic location of injury or illness.

MSD, one of the largest class of health effects (Timpka et al., 2014; Woolf et al., 2012; Woolf et al., 2010; Freburger et al., 2009; Sinnott and Wagner, 2009; Brooks, 2006), is caused by various factors, work related and nonwork related, and rates of MSD vary by population, their age groups, genders and other factors. Prevalence rates have been reported ranging from 35% for upper back MSD among health care workers (Long et al., 2013), to 90.6% lifetime prevalence for any MSD among farmers (Osborne et al., 2012). Determination of such rates for MSD depend on a range of factors such as type of study used to assess rates (Driscoll, 2011), definition of outcome used to assess MSD (Saarni et al., 2007), or use of a diagnosis code or rating of function to characterize MSD cases for analysis of health impacts, costs, and other effects (Rudolf et al., 2012; Kostanjsek et al., 2010). These factors can affect our understanding of the prevalence, incidence, and costs of MSD aside from the variability of actual prevalence or incidence rates due to etiologic issues or costs due to illness or injury severity or treatment response and recovery. The ICD-9 diagnosis and procedure, Diagnosis-related group (DRG), Current Procedural Terminology (CPT), and the Healthcare Common Procedure Coding System (HCPCS) codes (CMS, 2014) have been used to examine patterns of illness and injury and their management and outcomes in various types of data, and to determine costs associated with MSD. These codes, predominantly ICD-9 codes, have been used to evaluate medical costs in administrative databases (Sears et al., 2013; Lix et al., 2012), but there are challenges to these efforts. Codes that accurately capture MSD diagnoses (Sinnott et al., 2012) or procedures (Clement et al., 2013) require appropriate selection and validation (Walvern and Austen, 2012; Walvern et al., 2011) to avoid bias and results that lead to incorrect association of treatments with diagnoses (Clement et al., 2013; Ensor et al., 2013) and incorrect assessment of health impact, resource utilization, and costs (Benchimol et al., 2011; De Coster et al., 2006).

The economic burden of occupational MSD is very high. BLS reports that about 34 percent (BLS, 2013) of all occupational injuries involving days away from work are due to MSD. According to the current global burden of disease study, MSD are the second most common cause of disability worldwide, measured by years lived with disability (YLDs), with low back pain being the most frequent condition (Vos, et al., 2012). The study also found that disability due to MSD is estimated to have increased by 45% from 1990 to 2010, in

particular osteoarthritis, and is expected to continue to rise with an increasingly obese, sedentary and aging population. Earlier research on the global burden of occupational diseases and injuries found that the annual incidence of MSD represented 31% of all occupational diseases estimated in the world in 1994 (Leigh et al., 1995). Gardner *et al.,* (2008) identified MSD as the leading work-related health concern in the developed world, accounting for up to 30% of all injuries requiring time away from work. This study signifies that MSD are the most frequent occupational disease that affects workers throughout the world. The number of work-related diseases reported in Sweden in 2003 was 25,391 cases for employees and self-employed persons, with a rate of 61 cases per 10,000 workers. Swedish official statistics report that ergonomics factors (monotonous or unusually strenuous movements or work posture) were the cause of 58.5% of all work-related diseases with a rate of 35.7 cases per 10,000 workers (Sveriges Official Statistics, report 2005). Finland found 4,807 occupational diseases in 2002 (20 cases per 10,000 workers), out of which 28 percent were repetitive stress injuries (MSD caused by non-physiological stress in work such as repetitive and monotonous work, unusual working posture) with a rate of 5.7 cases per 10,000 workers. Diagnoses of specific repetitive stress injuries in Finland included mononeuropathy of upper and lower extremity, hand and arm vibration syndrome, epicondylitis, tenosynovitis, peritendinitis, and bursitis, among others (Riihimaki, et al., 2004). In 2012, 905,690 injuries and illnesses that required recuperation away from work were reported in private industries in USA. During the same year, over 388,060 MSD (34%) were reported, accounting for more than one in three injuries and illnesses with days away from work (BLS, 2013).

The magnitude of economic losses associated with MSD depends on several factors, for example, the severity of the condition, the nature and quality of health care received, characteristics of the patient, such as age and general health status, and how the loss is measured. Conventionally, costs of occupational diseases are classified into direct costs and indirect costs (Leigh et al., 2000). However, non-health related factors, for example, psychosocial factors, workplace characteristics, and availability of disability compensation, are also important determinants of the economic losses associated with MSD (Baldwin, 2004). In addition, the socioeconomic factors of populations in different countries influence the results of the magnitude of MSD (Andersson, 1998).

Researchers estimated losses due to MSD to range from 0.5% to 2% of GDP (Blair et al., 2003). In separate cost analysis for specific MSD, low back

pain (LBP) was found to be the most expensive MSD in the workplace. LBP causes the loss of 149 million workdays annually in USA (Guo et al., 1999). The cost of medical treatment for all work-related back pain was estimated as US $13 billion in 1990 with an estimated growth rate of 7% per year (Stratus, 2002). In 1992, back cases represented 24% of U.S. Workers' Compensation claims and 31% of the costs. The estimated cost of back problems between 1988 and 1992 in some states of the USA was US $8,244 per claim with 38% accounting for health-care cost, and 62% for indemnity costs (Williams et al., 1998). According to Gore et al., (2010) patients with chronic low back pain have greater comorbidity and economic burdens compared with those without chronic low back pain. This economic burden can be attributed to greater prescribing of pain-related medications and increased health resource utilization. According to Kartz (2006) total costs associated with low back pain in the United States exceed $100 billion per year, two-thirds of which are a result of lost wages and reduced productivity.

The median days away from work for MSD cases was 9 days in 2012, compared to 8 days in 2010 for all days away from work cases (BLS, 2011; BLS, 2013). According to the American Federation of Labor and Congress of Industrial Organizations (AFL-CIO) 2012 report 'Death on the Job, The Toll of Neglect: A National and State-By-State Profile of Worker Safety and Health In the United States', from 1992 through 2010, the percent of MSD were the highest in 2000 (35%) and total cases of MSD involving days away from work were the highest in 1992 (784,100) (AFL-CIO, 2012). The percent of MSD cases was 29.4 in 2008 and 2009 but increased to 30.5 percent in 2010 (AFL-CIO, 2012). The burden of MSD is not equally shared across the population. Sengupta et al., (2009) reported that the recovery time for musculoskeletal injuries increases significantly with age. Tanaka et al., (2001) estimated that about 40% of all upper extremity MSD in the US workforce was attributable to occupational exposures. There are also numerous studies estimating the costs of MSD in the United States (Webster and Snook, 1994, Brogmus et al., 1996, Hashemi et al., 1998, National Research Council and Institute of Medicine, 2001; Baldwin, 2004, Peele et al., 2005, Silverstein and Adams, 2007, the American Academy of Orthopedic Surgeons, 2008, and Dunning et al., 2010) and other countries (Woolf and Pfleger, 2003, and Piedrahita, 2006). Some of these studies include all MSD, some of them concentrate only on upper extremities, and others focus on some specific types of MSD. Most of these studies emphasize estimating direct costs of MSD. Bhattacharya (2014) evaluated research on direct and indirect costs of occupational MSD in the US and estimated the direct and indirect costs of

occupational MSD and CTS for the years 2003 through 2007. This study found that the direct costs of MSD were $1.5 billion and the indirect costs were $1.1 billion for the year 2007. Webster and Snook (1994) reported an average compensable cost of $8,070 per case for 1989 for "upper extremity cumulative trauma disorder" claims from a large, national Workers' Compensation (WC) insurance carrier with coverage in 45 jurisdictions. The median cost was $824. Brogmus et al., (1996) found that work-related MSD of the upper extremity averaged $6,760 per claim for the year 1992. This average was 80% higher than the average of all claims ($3,723) reported to Liberty Mutual in 1992. According to 1995 estimates by the National Research Council and the Institute of Medicine (2001), annual direct costs of all MSD (occupational and non-occupational MSD) were $215 billion, whereas estimates for work-related MSD ranged between $45 and $54 billion for the year 1998. Morse et al., (1998) found that work-related MSD significantly reduced the ability of individuals to perform activities of daily living in Connecticut. Silverstein and Adams (2007, a technical report) reported that the direct costs of work-related MSD of neck, back and upper extremity were $6.8 billion and averaged $11,903 per case during the years 1997 through 2005 for the state of Washington. Dunning et al., (2010) utilized WC claims data from the Ohio Bureau of Workers' Compensation (OBWC) and found that the average total cost per claim was $5,130 (medical costs were $2,924 and indemnity costs were $,2206). The American Academy of Orthopedic Surgeons (2008), editor of 'The Burden of Musculoskeletal Diseases in US' (page 227), used data from the Medical Expenditure Panel Survey and stated that the US average per person cost of MSD for all population (both working and non-working populations) was $5,824 for the years 2002–2004. Most of the research described above has focused on costs of MSD and economic burden. This chapter focuses on types of MSD diagnosis in a dataset of employed individuals and associated medical costs and demographic factors. Several types of MSD are examined in this chapter.

## Data and Methodology

### Data

MarketScan databases are used to analyze medical costs by ICD-9 codes for the year 2010. These databases consist of millions of records on medical

claims classified by ICD-9 codes, different medical cost components and some socioeconomic and demographic variables. This database is focused on healthcare costs and contains information on employees of participating employers including utilization of medical care, the industry they are employed in, their gender, age group, and region (a description of the MarketScan databases is available on request, Hansel and Chang, 2010 white papers). The data comprise inpatient, outpatient, and pharmacy services covered by group health insurance system for employed individuals aged zero to 64. MarketScan data specifies for each month in which an employee is enrolled for medical insurance the employee age, gender, type of health insurance coverage, region of the U.S., industrial sector, and employee status (hourly/salaried; union/non-union). Seven industrial sectors were represented: retail trade; transportation, communication and utilities; manufacturing durables; manufacturing non-durables; services; finance, insurance and real estate; and oil and gas extraction/mining. The regions included South, Northeast, North Central, West and "unknown." The data released by Thomson Reuters MarketScan to external clients has been certified as de-identified according to HIPAA rules. Due to these stringent confidentiality requirements, workers could not be classified by individual (identity-protected) employer.

The data used in this study consists of medical expenses of individuals classified by ICD-9 codes related to MSD, and the corresponding procedure codes, and DRG codes of the individuals that filed for these MSD related medical claims. Expenses related to these medical claims are estimated as the *total costs* including out-of-pocket expenses not covered by the insurance benefits. The group health medical expenditure can run from a nominal amount for individuals with few medical claims to very large numbers for those with numerous medical claims related to MSD. The distribution, therefore, is a normal distribution as the medical expenses are continuous in nature.

The data used here from MarketScan databases are comprised of medical claims classified by two primary categories, inpatient admissions and outpatient services for the year 2010. These medical claims were classified by different demographic variables and the final inpatient database had 18,209 employees that had filed for 29,250 medical claims related to MSD. The average cost for an MSD claim was $65,236.

Table 1a illustrates the descriptive statistics of the inpatient admission claims of the population studied here by their demographic variables. The

sample had 53 percent females with most of them in the age group of 55 to 64 years employed mostly in the manufacturing, durable sector.

**Table 1a. Demographics for Inpatient Admissions. Age, gender, and industry variables were assessed in the Medstat database as discussed in the methods**

| | | Age groups | | | | | |
|---|---|---|---|---|---|---|---|
| Industry | Gender | 0-17 years | 18-34 years | 35-44 years | 45-55 years | 55-64 years | Total |
| Oil, Gas and Mining | Male | 8 | 19 | 28 | 53 | 41 | 149 |
| | Female | 10 | 27 | 36 | 68 | 35 | 176 |
| Manufacturing, Durable | Male | 63 | 117 | 311 | 598 | 562 | 1651 |
| | Female | 98 | 167 | 332 | 647 | 507 | 1751 |
| Manufacturing, Nondurable | Male | 33 | 86 | 200 | 319 | 232 | 870 |
| | Female | 69 | 87 | 208 | 322 | 189 | 875 |
| Transportation, Communication, and Utilities | Male | 44 | 148 | 288 | 414 | 340 | 1234 |
| | Female | 109 | 191 | 314 | 421 | 310 | 1345 |
| Retail | Male | 12 | 30 | 62 | 97 | 69 | 270 |
| | Female | 12 | 41 | 55 | 93 | 101 | 302 |
| Finance, Insurance and Real Estate | Male | 48 | 149 | 214 | 314 | 294 | 1019 |
| | Female | 79 | 204 | 257 | 355 | 230 | 1125 |
| Services | Male | 52 | 144 | 293 | 394 | 413 | 1296 |
| | Female | 90 | 267 | 318 | 489 | 480 | 1644 |
| *All* | *Male* | 348 | 876 | 1807 | 2846 | 2640 | 8517 |
| | *Female* | *616* | *1,283* | *2,006* | *3,220* | *2,566* | *9,691* |

The sample had the highest number of male population in the age group of 45 to 54 years of age, and most of them were employed in the manufacturing, durable sector. Most of the sample resided in the southern region (not noted in the table).

Table 1b illustrates the descriptive statistics of the outpatient services medical claims by their demographic variables. The final outpatient database had 2,053,331 employees that had filed for 5,896,443 medical claims related

to MSD. The sample had 56 percent females with most of them in the age group of 45 to 54 years with the highest employment in the services sector. The sample had the highest number of male population in the age group of 45 to 54 years of age, and most of them were employed in the manufacturing, durable sector. Most of the sample resided in the southern region (not illustrated in the table).

**Table 1b. Demographics for Outpatient Admissions. Age, gender, and industry variables were assessed in the Medstat database as discussed in the methods**

| | | Age groups | | | | | |
|---|---|---|---|---|---|---|---|
| **Industry** | **Gender** | **0-17 years** | **18-34 years** | **35-44 years** | **45-54 years** | **55-64 years** | **All** |
| Oil, Gas and Mining | Male | 771 | 2,637 | 3,353 | 5,569 | 4,172 | 16,502 |
| Manufacturing, Durable | Male | 9,563 | 19,279 | 32,520 | 58,231 | 40,554 | 160,147 |
| | Female | 15,724 | 20,445 | 36,212 | 63,901 | 41,032 | 177,314 |
| Manufacturing, Nondurable | Male | 5,015 | 11,108 | 20,375 | 27,150 | 17,769 | 81,417 |
| | Female | 9,439 | 11,671 | 20,018 | 30,415 | 16,391 | 87,934 |
| Transportation, Communication and Utilities | Male | 8,867 | 24,494 | 39,509 | 48,347 | 29,566 | 150,783 |
| | Female | 15,668 | 26,682 | 40,618 | 55,419 | 29,781 | 168,168 |
| Retail Trade | Male | 1,267 | 3,939 | 5,979 | 7,325 | 5,917 | 24,427 |
| | Female | 2,159 | 5,678 | 6,513 | 10,282 | 7,778 | 32,410 |
| Finance, Insurance and Real estate | Male | 7,174 | 21,246 | 28,024 | 28,840 | 20,951 | 106,235 |
| | Female | 13,102 | 25,422 | 32,006 | 37,204 | 24,143 | 131,877 |
| Services | Male | 13,944 | 29,628 | 39,531 | 44,145 | 37,003 | 164,251 |
| | Female | 20,797 | 49,913 | 54,118 | 66,761 | 50,102 | 241,691 |
| All | Male | 58,154 | 140,515 | 217,067 | 284,398 | 213,206 | 913,340 |
| | Female | 97,382 | 180,671 | 252,143 | 363,834 | 245,646 | 1,139,676 |

## Methodology

### *ICD-9, DRG, and Procedure Codes*

Selection of MSD related ICD-9 codes was based on codes suggested by a review of several studies that evaluated specific ICD-9 codes for neck, upper back, and lower back MSD (Sinnott et al., 2012). A list of 122 unique ICD-9

codes was identified for use in the present analysis. Codes related to fracture, pediatric or congenital diagnoses were excluded from this analysis. Codes related to dislocation were included since fracture-dislocation situations should have fracture coded as the diagnosis. The consideration of spinal curvature codes is supported by several reports in the literature. Increased lumbar spine stiffness was found to occur even after 1 hour (in men) or 2 hours (in women) of continuously working on office work tasks in a sitting posture (Beach et al., 2005). Concurrent decreases in low back pain and improvement in thoracic kyphosis and lumbar lordosis (as measured biomechanically) have been observed in nurses participating in a spine training program (Jaromi et al., 2012). An earlier study found an association between a diagnosis of scoliosis and report of chronic low back pain in the preceding year in nurses (Violante et al., 2004). A study of oyster shuckers, who have among their occupational exposures standing for long periods of time in awkward postures, with sustained neck and back flexion, were found to have higher levels of kyphosis than the general population (Hsu et al., 2011). In light of such information, codes related to spinal curvature (scoliosis, kyphosis, and lordosis) from Sinnott and colleagues (2012) were included in this analysis. A full listing of this starting pool of ICD-9 codes is available upon request from the authors.

### *Formulation of Body Region Variables*

Body region designations for ICD-9 codes were assigned based on whether the diagnosis was nonspecific, neck (cervical), upper back (thoracic), or lower back (lumbar). The non-specific category includes codes that relate to "not otherwise specified" designations, multiple site diagnoses, or codes that for one reason or another do not specify a body region. Diagnoses that related to both the thoracic and lumbar regions were included in the lumbar region category. The number of codes in each group was as follows: nonspecific=39, neck (cervical) =39, upper back (thoracic) =14 and lower back (lumbar) =30.

### *Data Extraction and Analyses*

Records were extracted from the data that had a medical claim related to one of the 122 ICD-9 codes of neck, upper back, or lower back MSD. Costs were analyzed for body region, and data for the top ICD-9, DRG, and CPT codes were examined with further descriptive analyses. Multinomial logistic regression analysis was conducted to examine the costs for different body regions. Statistical analyses were conducted using Stata and SAS (Stata, 2013; SAS, 2010). The body parts were used as the dependent variable. The different

demographic variables and logarithm of total costs of each individual for the different medical claims were used as the independent variables.

## Results

Analysis of costs examined average cost per person by body regions and demographic variables. These costs were analyzed using medical claims data on inpatient admissions and outpatient services (Table 2). The overall average costs per person by body region was $63,055 (inpatient)/$253 (outpatient) for neck, $89,500/$288 for upper back, and $55,537/$380 for lower back, whereas the non-specific diagnoses had the highest average cost for inpatient admissions at $105,489 and lowest for outpatient services at $246. Costs for inpatient admissions exceed outpatient care by a factor of 200 or more.

Analysis of average costs per person for individual ICD-9 codes is presented in Tables 3a and 3b. Analysis of inpatient admissions (Table 3a) revealed that while the highest cost was for code 839.21 (closed dislocation of thoracic vertebra), the average costs for the top fifteen diagnoses ranged from $111,650 to $257,645. In these fifteen codes, six codes were related to spinal curvature diagnoses, one code was related to intervertebral disc disease in the thoracic region, one code was related to spondylosis (unspecified), and the remainder were related to dislocation of vertebra at various cervical and thoracic levels. Forty-seven of the top fifty codes (20 of these codes are represented in Table 3a and the rest are in Appendix A) with the highest average cost had an N greater than 2. Among these, 9,748 individuals had a diagnosis of intervertebral disc related disorders (12 ICD-9 codes), 4,869 individuals had diagnoses related to spinal stenosis codes (2 codes), and 2,431 had diagnoses related to spinal curvature diagnoses (11 codes).

Other code related groups included those related to vertebral dislocations (N=120), spondylosis with or without myelopathy (N=276), and postlaminectomy syndromes (N=469). The diagnosis of other, pain disorder related to psychological factors occurred for 1,478 individuals with an inpatient average cost per person of $36,411.

Among outpatient records (Table 3b), the highest average cost is for ICD-9 code 737.21, lordosis postlaminectomy, with an average cost of $1,169 for 124 individuals in the dataset.

**Table 2a. Percentage Distribution of Demographic Variables and Average Costs by Body Region for the Inpatient Admissions**

| Body Region | Nonspecific | | | Neck (Cervical) | Upper Back (Thoracic) | | Lower Back (Lumbar) | | All |
|---|---|---|---|---|---|---|---|---|---|
| | Percentage (%) | Average Costs ($) | Percentage (%) | Average Costs ($) | Percentage (%) | Average Costs ($) | Percentage (%) | Average Costs ($) | Average Costs ($) |
| Females | 11 | 99,868 | 5 | 59,111 | 2 | 77,684 | 35 | 55,926 | 65,739 |
| Males | 5 | 117,419 | 5 | 67,387 | 2 | 103,027 | 35 | 55,146 | 64,662 |
| 0-17 | 4.5 | 7,847 | 0.18 | 127,177 | 0.1 | 87,160 | 0.52 | 54,039 | 111,372 |
| 18-34 | 2.81 | 65,059 | 0.67 | 49,626 | 0.47 | 92,628 | 7.91 | 45,091 | 51,945 |
| 35-44 | 1.83 | 67,386 | 2.34 | 56,242 | 0.59 | 57,778 | 16.17 | 51,889 | 53,900 |
| 45-54 | 3 | 118,255 | 4.44 | 59,969 | 1.17 | 85,351 | 24.7 | 57,178 | 64,046 |
| 55-64 | 3.5 | 131,044 | 2.77 | 72,811 | 0.92 | 113,819 | 21.4 | 60,303 | 71,897 |
| Oil, Gas and Mining | 0.32 | 83,422 | 0.37 | 54,178 | 0.05 | 62,411 | 1.63 | 55,473 | 59,203 |
| Manufacturing, Durable | 3.29 | 114,812 | 2.44 | 56,748 | 0.8 | 60,523 | 18.29 | 50,924 | 60,275 |
| Manufacturing, Nondurable | 1.71 | 95,783 | 1.33 | 53,762 | 0.43 | 120,399 | 9.27 | 50,118 | 58,993 |
| Transportation, Communication and Utilities | 3.22 | 119,801 | 1.82 | 60,146 | 0.66 | 91,653 | 13.12 | 56,870 | 69,175 |
| Retail Trade | 0.69 | 107,812 | 0.44 | 60,557 | 0.08 | 44,956 | 2.96 | 58,751 | 66,823 |
| Finance, Insurance and Real estate | 2.34 | 106,046 | 1.84 | 69,749 | 0.45 | 87,586 | 11.01 | 55,475 | 65,653 |
| Services | 3.61 | 94,092 | 2.25 | 55,971 | 0.71 | 70,943 | 14.87 | 52,057 | 60,174 |
| Northeast | 1.83 | 119,000 | 1.21 | 57,804 | 0.37 | 87,664 | 8.49 | 48,801 | 61,710 |
| North Central | 3.67 | 92,435 | 1.88 | 58,673 | 0.82 | 73,019 | 17.11 | 51,698 | 59,378 |
| South | 6.1 | 103,833 | 4.85 | 56,382 | 1.3 | 85,485 | 29.02 | 56,467 | 64,368 |
| West | 3.98 | 114,706 | 2.43 | 82,520 | 0.76 | 115,198 | 15.95 | 61,704 | 74,772 |
| Unknown | 0.06 | 49,759 | 0.02 | 40,766 | | | 0.14 | 37,696 | 41,243 |
| All | 15.64 | 105,489 | 10.4 | 63,055 | 3.25 | 89,500 | 70.71 | 55,537 | 65,236 |

**Table 2b. Percentage Distribution of Demographic Variables and Average Costs by Body Region for the Outpatient Services**

| Body Region | Nonspecific | | Neck (Cervical) | | Upper Back (Thoracic) | | Lower Back (Lumbar) | | All |
|---|---|---|---|---|---|---|---|---|---|
| | Percentage (%) | Average Costs ($) | Percentage (%) | Average Costs ($) | Average Costs ($) | Average Costs ($) | Percentage (%) | Average Costs ($) | Average Costs ($) |
| Females | 7.98 | 244 | 6.12 | 257 | 3.8 | 294 | 37.62 | 372 | 335 |
| Males | 3.95 | 248 | 3.76 | 247 | 2.9 | 280 | 33.88 | 387 | 356 |
| 0-17 | 5.09 | 202 | 0.83 | 166 | 0.51 | 198 | 1.14 | 245 | 204 |
| 18-34 | 1.92 | 235 | 1.92 | 205 | 1.46 | 250 | 10.35 | 355 | 312 |
| 35-44 | 1.45 | 265 | 2.47 | 254 | 1.6 | 288 | 17.33 | 379 | 352 |
| 45-54 | 1.96 | 293 | 3.01 | 285 | 1.93 | 311 | 24.68 | 385 | 365 |
| 55-64 | 1.51 | 325 | 1.65 | 29 | 1.19 | 333 | 18 | 393 | 378 |
| Oil, Gas and Mining | 0.26 | 227 | 0.13 | 294 | 0.13 | 299 | 1.79 | 420 | 384 |
| Manufacturing, Durable | 2.44 | 228 | 2.05 | 230 | 1.15 | 295 | 15.95 | 380 | 344 |
| Manufacturing, Nondurable | 1.26 | 248 | 0.91 | 264 | 0.57 | 303 | 8.1 | 418 | 379 |
| Transportation, Communication and Utilities | 2.51 | 240 | 1.43 | 273 | 1.36 | 303 | 15.11 | 385 | 354 |
| Retail Trade | 0.42 | 235 | 0.26 | 248 | 0.19 | 318 | 2.78 | 374 | 346 |
| Finance, Insurance and Real estate | 2.16 | 247 | 1.12 | 231 | 0.83 | 305 | 11.13 | 385 | 350 |
| Services | 2.44 | 256 | 5.35 | | 2.31 | 252 | 15.87 | 360 | 316 |
| Northeast | 1.85 | 228 | 0.84 | 253 | 0.64 | 329 | 8.64 | 387 | 350 |
| North Central | 2.44 | 258 | 5.36 | 227 | 2.47 | 244 | 18.34 | 351 | 310 |
| South | 4.84 | 248 | 2.12 | 314 | 1.97 | 311 | 30.74 | 376 | 354 |
| West | 2.75 | 243 | 1.55 | 259 | 1.6 | 309 | 13.62 | 420 | 373 |
| Unknown | 0.05 | 243 | 0.01 | 245 | 0.01 | 345 | 0.16 | 388 | 333 |
| All | 11.93 | 246 | 9.87 | 253 | 6.7 | 288 | 71.5 | 380 | 345 |

Tables 2a and 2b. Inpatient (2a) and Outpatient (2b) Average Costs by Body Regions and Demographic Variables: The table presents the costs for data evaluated from the Medstat database, as described in the methods, by body regions and demographic variables.

## Table 3a. Average Costs by ICD-9 Codes, Body Regions– Inpatient Admissions

| ICD-9 | Diagnosis | Body Region | N | Minimum Cost | Maximum Cost | Average Cost |
|---|---|---|---|---|---|---|
| 83921 | Closed dislocation thoracic vertebra | Upper Back (Thoracic) | 11 | 1,982 | 815,136 | 257,645 |
| 83906 | Closed dislocation sixth cervical vertebra | Neck (Cervical) | 27 | 2,800 | 960,585 | 196,000 |
| 73743 | Scoliosis associated with other conditions | Nonspecific | 102 | 2,200 | 1,009,265 | 195,855 |
| 73739 | Other kyphosis and scoliosis | Nonspecific | 297 | 2,200 | 1,767,411 | 194,381 |
| 83901 | Closed dislocation first cervical vertebra | Neck (Cervical) | 18 | 11,093 | 1,283,143 | 189,957 |
| 73740 | Unspecified curvature of spine associated with other conditions | Nonspecific | 7 | 7,328 | 642,250 | 182,631 |
| 83902 | Closed dislocation second cervical vertebra | Neck (Cervical) | 10 | 12,483 | 927,736 | 178,245 |
| 72272 | Intervetebral disc disorder with myelopathy thoracic region | Upper Back (Thoracic) | 61 | 6,844 | 1,677,783 | 168,960 |
| 83903 | Closed dislocation third cervical vertebra | Neck (Cervical) | 7 | 32,103 | 626,817 | 168,430 |
| 83908 | Closed dislocation multiple cervical vertebrae | Neck (Cervical) | 20 | 3,058 | 558,142 | 140,235 |
| 73729 | Other lordosis acquired | Nonspecific | 22 | 6,698 | 678,102 | 139,023 |
| 73719 | Other kyphosis acquired | Nonspecific | 49 | 1,592 | 326,183 | 124,555 |
| 72191 | Spondylosis of unspecified site with myelopathy | Nonspecific | 17 | 12,242 | 605,391 | 119,308 |
| 83905 | Closed dislocation fifth vertebra | Neck (Cervical) | 13 | 3,276 | 604,938 | 116,148 |
| 73734 | Thoracogenic scoliosis | Upper Back (Thoracic) | 30 | 12,016 | 450,791 | 111,650 |
| 73710 | Kyphosis (acquired) (postural) | Nonspecific | 201 | 1,120 | 770,125 | 110,989 |
| 83907 | Closed dislocation seventh cervical vertebra | Neck (Cervical) | 10 | 7,532 | 364,428 | 106,923 |

| ICD-9 | Diagnosis | Body Region | N | Minimum Cost | Maximum Cost | Average Cost |
|---|---|---|---|---|---|---|
| 83904 | Closed dislocation fourth cervical vertebra | Neck (Cervical) | 15 | 10,932 | 536,216 | 101,938 |
| 73730 | Scoliosis (and kyphoscoliosis) idopathic | Nonspecific | 1671 | - | 2,060,064 | 99,468 |
| 72282 | Postlaminectomy syndrome of thoracic region | Upper Back (Thoracic) | 20 | 13,635 | 661,909 | 95,320 |

## Table 3b. Average Costs by ICD-9 Codes, Body Regions– Outpatient Services

| ICD-9 | Diagnosis | Body Region | N | Minimum Cost | Maximum Cost | Average Cost |
|---|---|---|---|---|---|---|
| 73721 | Lordosis postlaminectomy | Nonspecific | 124 | 0 | 7567.559 | 1169.701 |
| 72282 | Postlaminectomy syndrome of the thoracic region | Upper Back (Thoracic) | 1292 | 0 | 105699.6 | 944.4302 |
| 72232 | Schmorl's nodes of lumbar region | Upper Back (Thoracic) | 1267 | 0 | 13357.01 | 660.6234 |
| 72280 | Postlaminectomy syndrome of unspecified region | Nonspecific | 4216 | 0 | 123875.2 | 640.6244 |
| 72231 | Schmorl'e nodes of thoracic region | Neck (Cervical) | 673 | 0 | 10776.48 | 628.1806 |
| 73722 | Other postsurgical lordosis | Nonspecific | 33 | 0 | 5436.52 | 573.1309 |
| 72402 | Spinal stenosis, lumbar region, without neurogenic claudication | Lower Back (Lumbar) | 164655 | 0 | 576000 | 558.7106 |
| 72283 | Postlaminectomy syndrome of lumbar region | Lower Back (Lumbar) | 72333 | 0 | 228544.6 | 518.212 |
| 73712 | Kyphosis postlaminectomy | Nonspecific | 132 | 0 | 19500 | 502.5141 |
| 72292 | Other and unspecified disc disorder of thoracic region | Upper Back (Thoracic) | 2830 | 0 | 52424.78 | 444.057 |

## Table 3b. (Continued)

| ICD-9 | Diagnosis | Body Region | N | Minimum Cost | Maximum Cost | Average Cost |
|---|---|---|---|---|---|---|
| 72239 | Schmorl's nodes of other spinal region | Nonspecific | 109 | 0 | 6686.706 | 434.2996 |
| 72293 | Other and unspecified disc disorder of lumbar region | Lower Back (Lumbar) | 38030 | 0 | 135522.1 | 416.1764 |
| 72271 | Intervetebral disc disorder with myelopathy cervical region | Neck (Cervical) | 27277 | 0 | 182600 | 405.5709 |
| 83918 | Open dislocation multiple cervical vertebrae | Neck (Cervical) | 40 | 0 | 3808 | 402.4312 |
| 72210 | Displacement of lumbar intervertebral disc without myelopathy | Lower Back (Lumbar) | 509568 | 0 | 203999.9 | 396.5939 |
| 72141 | Spondylosis with myelopathy thoracic region | Upper Back (Thoracic) | 1924 | 0 | 54527.88 | 387.083 |
| 72211 | Displacement of thoracic intervertebral disc without myelopathy | Upper Back (Thoracic) | 25282 | 0 | 56989.05 | 380.8786 |
| 72401 | Spinal stenosis of thoracic region | Upper Back (Thoracic) | 4538 | 0 | 53898.26 | 368.6751 |
| 72291 | Other and unspecified disc disorder of cervical region | Neck (Cervical) | 19258 | 0 | 36727.03 | 364.2701 |
| 72272 | Intervertebral disc disorder with myelopathy thoracic region | Upper Back (Thoracic) | 2161 | 0 | 19262.66 | 357.8098 |

*Legend:* Tables 3a and 3b. Average Costs by ICD-9 Codes, Body Regions. The top 20 ICD-9 codes with the highest average costs per person are presented with inpatient data in Table 3a and outpatient data in Table 3b. The following 30 ICD-9 codes with the highest average costs per person are presented with inpatient data in Appendix A and outpatient data in Appendix B.

## Table 4a. Average Costs and Number of People by DRGs, CPTs, ICD-9 Codes, Body Regions– Inpatient Admissions

| DRG Codes | | Procedure Codes | | ICD-9 Codes | Diagnosis | Body Regions | N | Minimum Cost | Maximum Cost | Average Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| 454 | Combined anterior/ posterior spinal fusion with CC | 8105 | Dorsal and dorsolumbar fusion of the posterior column, posterior technique | 73730 | Scoliosis (and kyphoscoliosis) idiopathic | Nonspecific | 6 | 167,382 | 773,802 | 524,106 |
| 454 | Combined anterior/ posterior spinal fusion with CC | 8106 | Lumbar and lumbosacral fusion of the anterior column, anterior technique | 73730 | Scoliosis (and kyphoscoliosis) idiopathic | Nonspecific | 13 | 105,866 | 650,725 | 303,774 |
| 456 | Spinal fusion except cervical with spinal curvature/malignancy/infection or extensive fusions with major complications and comorbidities | 8105 | Dorsal and dorsolumbar fusion of the posterior column, posterior technique | 73739 | Other kyphoscoliosis and scoliosis | Nonspecific | 6 | 28,213 | 572,142 | 301,337 |
| 456 | Spinal fusion except cervical with spinal curvature/malignancy/infection or extensive fusions with major complications and comorbidities | 8105 | Dorsal and dorsolumbar fusion of the posterior column, posterior technique | 73739 | Other kyphoscoliosis and scoliosis | Nonspecific | 14 | 56,509 | 612,065 | 291,851 |
| 457 | Spinal fusion except cervical with spinal curvature/malignancy/infection or extensive fusions with complications and comorbidities | 8105 | Dorsal and dorsolumbar fusion of the posterior column, posterior technique | 73739 | Other kyphoscoliosis and scoliosis | Nonspecific | 15 | 36,856 | 714,039 | 289,008 |
| 456 | Spinal fusion except cervical with spinal curvature/malignancy/infection or extensive fusions with major complications and comorbidities | 8105 | Dorsal and dorsolumbar fusion of the posterior column, posterior technique | 73730 | Scoliosis (and kyphoscoliosis) idiopathic | Nonspecific | 40 | 29,872 | 1,264,711 | 269,420 |

## Table 4a. (Continued)

| DRG Codes | | Procedure Codes | | ICD-9 Codes | Diagnosis | Body Regions | N | Minimum Cost | Maximum Cost | Average Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| 457 | Spinal fusion except cervical with spinal curvature/malignancy/infection or extensive fusions with complications and comorbidities | 8105 | Dorsal and dorsolumbar fusion of the posterior column, posterior technique | 73739 | Other kyphoscoliosis and scoliosis | Nonspecific | 13 | 71,947 | 627,912 | 265,542 |
| 454 | Combined anterior/ posterior spinal fusion with CC | 8108 | Lumbar and lumbosacral fusion of the anterior column, posterior technique | 73730 | Scoliosis (and kyphoscoliosis) idiopathic | Nonspecific | 7 | 125,953 | 484,440 | 227,954 |
| 458 | Spinal fusion except cervical with spinal curvature/malignancy/infection or extensive fusions without major complications and comorbidities | 8108 | Lumbar and lumbosacral fusion of the anterior column, posterior technique | 73739 | Other kyphoscoliosis and scoliosis | Nonspecific | 6 | 47,567 | 591,330 | 227,687 |
| 454 | Combined anterior/ posterior spinal fusion with CC | 8106 | Lumbar and lumbosacral fusion of the anterior column, anterior technique | 72402 | Spinal stenosis, lumbar region, without neurogenic claudication | Lower Back (Lumbar) | 8 | 9,606 | 720,676 | 217,241 |

## Table 4b. Average Costs and Number of People by CPTs, ICD-9 Codes, Body Regions– Outpatient Services

| Procedure Codes | | ICD-9 | Diagnosis | Body Regions | N | Minimum Cost | Maximum Cost | Average Cost |
|---|---|---|---|---|---|---|---|---|
| C1820 | Generator, neurostimulator (implantable), with rechargeable battery and charging system | 72283 | Postlaminectomy syndrome of lumbar region | Lower Back (Lumbar) | 31 | 0 | 80596.06 | 26425.43 |
| C1820 | Generator, neurostimulator (implantable), with rechargeable battery and charging system | 72252 | Degeneration of lumbar or lumbosacral intervertebral disc | Lower Back (Lumbar) | 6 | 10178.25 | 55502.34 | 24883.55 |
| L8687 | Implantable neurostimulator pulse generator, dual array, rechargeable, includes extension | 72283 | Postlaminectomy syndrome of lumbar region | Lower Back (Lumbar) | 12 | 0 | 43188 | 22069.18 |
| J1745 | Injection infliximab, 10 mg | 72190 | Spondylosis of unspecified site with myelopathy | Nonspecific | 8 | 2582.129 | 112565.3 | 20668 |
| L8699 | Prosthetic implant, not otherwise specified | 73730 | Scoliosis (and kyphoscoliosis) idiopathic | Nonspecific | 6 | 0 | 40500 | 17925.09 |
| L8699 | Prosthetic implant, not otherwise specified | 72402 | Spinal stenosis, lumbar region, without neurogenic claudication | Lower Back (Lumbar) | 17 | 3.83 | 57563.34 | 17057.81 |
| C1772 | Infusion pump, programmable (implantable) | 72283 | Postlaminectomy syndrome of lumbar region | Lower Back (Lumbar) | 9 | 0 | 37656.88 | 16020.6 |

## Table 4b. (Continued)

| Procedure Codes | | ICD-9 | Diagnosis | Body Regions | N | Minimum Cost | Maximum Cost | Average Cost |
|---|---|---|---|---|---|---|---|---|
| 63056 | Transpedicular approach with decompression of spinal cord, equina and/or nerve root(s) (e.g., herniated intervertebral disc), single segment; lumbar (including transfacet, or lateral extraforaminal approach) (e.g., far lateral herniated intervertebral disc) | 72273 | Intervertebral disc disorder with myelopathy lumbar region | Lower Back (Lumbar) | 27 | 201.0099 | 55000 | 14999.4 |
| 63030 | lumbar discectomy [laminotomy (hemilaminectomy), with decompression of nerve root(s), including partial facetectomy, foraminotomy and/or excision of herniated intervertebral disc, 1 interspace, lumbar] | 72283 | Postlaminectomy syndrome of lumbar region | Lower Back (Lumbar) | 10 | 216.36 | 84168.88 | 14082.27 |
| L8699 | Prosthetic implant, not otherwise specified | 72252 | Degeneration of lumbar or lumbosacral intervertebral disc | Lower Back (Lumbar) | 10 | 6.389999 | 29087.45 | 13823.16 |

*Legend:* Tables 4a and 4b. Average Costs by DRG, procedure, and ICD-9 codes. The top ten DRG codes with the highest average costs per person are presented with inpatient data in Table 4a and the top ten procedure codes with the highest average costs per person in the outpatient data are presented in Table 4b. Average costs per person were assessed in the inpatient data by DRG code, then results with only one observation were removed, and the results ordered by average cost. Similarly, outpatient data was analyzed for average costs per person by procedure code, results with only one observation excluded, and remaining results ordered by average cost. Procedure codes and ICD-9 codes associated with the DRG code are listed in Table 4a, and the ICD-9 code associated with the procedure code are listed in Table 4b.

In the fifty codes (20 of these are represented in Table 3b and the rest are in Appendix B) with the highest average costs per person, 12 codes were related to intervertebral disc disorders (N=1,190,877 individuals), 8 codes were for diagnoses related to the curvature of the spine (N=177,817), 2 codes were diagnoses for lumbar (predominantly) and thoracic stenosis (N=169,193), 11 codes were related to cervical and thoracic dislocation (N=131,396), 7 codes were related to postlaminectomy diagnoses (N=93,311), and 3 codes were related to spondylosis diagnoses (N=39,201). The diagnosis of other, pain disorder related to psychological factors occurred for 6,471 individuals with an outpatient average cost per person of $237,whereas those related to inpatient admissions was $36,411.

Tables 4a and 4b present analyses of average costs per person for DRG and procedure codes. These costs were calculated for the data analyzed in Tables 2 and 3 by DRG code, then costs in which only one observation was used to calculate the value were excluded, and then the data ordered by cost. Among the inpatient data, the analysis results of which are presented in Table 4a, the highest average cost per person by DRG code was for DRG code 454, combined anterior/posterior spinal fusion with complications and comorbidities, for 6 individuals in the dataset. This DRG code was associated with an MSD ICD-9 code of 737.30, scoliosis (and kyphoscoliosis) idiopathic. Among the top ten highest average cost per person DRG codes, nine were spinal fusion procedures associated with ICD-9 codes related to spinal curvature diagnoses. For the outpatient data, the average cost per person for the highest costing procedure code was for implantation of a generator, neurostimulators (implantable), with rechargeable battery and charging system, procedure code C1820, for 31 individuals in the dataset and association with an ICD-9 code of 722.83, postlaminectomy syndrome of lumbar region. Of the top ten highest average costs per person by procedure codes, presented in Table 4b, seven were for implantable neurostimulators or other devices, and two were for laminectomy procedures.

Multinomial logistic regression analysis evaluated differences across body region groups, incorporating the independent variables of gender, age groups, geographic location, industry type, and logarithm of total cost per person into models, using data for referenced ICD-9 codes. In these analyses, the referent group is female, age 35-44, works in the manufacturing/non-durable goods sector, and resides in the southern region of the US. These analyses, presented in Tables 5 (inpatient) and 6 (outpatient) indicate several differences across body region groups.

**Table 5. Multinomial Logit Regression of Body Regions of Neck (Cervical), Upper Back (Thoracic), and Lower Back (Lumbar) Adjusting for Age, Gender, Geographic, and Industry Variables – Inpatient Analysis**

| Effect | Odds Ratio | 95% Wald | |
|---|---|---|---|
| | Point Estimate | Confidence Limits | |
| Neck Body Region | | | |
| Male | 1.95* | 1.71 | 2.22 |
| Oil, Gas and Mining | 1.86* | 1.17 | 2. |
| Manufacturing, Durable | 1.15 | .970 | 1.38 |
| Transportation, Communication and Utilities | .884 | .73 | 1.07 |
| Retail | .957 | .673 | 1.3 |
| Finance, Insurance and Real estate | 1.41* | 1.15 | 1.73 |
| North East | .796* | .645 | .9 |
| North Central | .620* | .523 | .73 |
| West | .718* | .612 | .84 |
| 0 – 17 years | .031* | .021 | .04 |
| 18 - 34 years | .184* | .144 | .24 |
| 45 - 54 years | 1.18 | .989 | 1.42 |
| 55 - 64 years | .626* | .520 | .75 |
| Log(Total Cost) | .877* | .829 | .93 |
| Upper Back Body Region | | | |
| Male | 1.88* | 1.56 | 2.26 |
| Oil, Gas and Mining | .81 | .358 | 1.87 |
| Manufacturing, Durable | 1.10 | .859 | 1.42 |
| Transportation, Communication and Utilities | .98 | .755 | 1.2 |
| Retail | .519* | .272 | .98 |
| Finance, Insurance and Real estate | 1.0 | .741 | 1.37 |
| North East | .917 | .674 | 1.24 |
| North Central | 1.01 | .801 | 1.28 |

| Effect | Odds Ratio | 95% Wald | |
|---|---|---|---|
| | Point Estimate | Confidence Limits | |
| West | .827 | .652 | 1.04 |
| 0 – 17 years | .067* | .040 | .11 |
| 18 - 34 years | .520* | .379 | .71 |
| 45 - 54 years | 1.21 | .931 | 1.59 |
| 55 - 64 years | .814 | .61 | 1.07 |
| Log(Total Cost) | .936 | .863 | 1.01 |
| Lower Back Body Region | | | |
| Male | 2.12* | 1.92 | 2.34 |
| Oil, Gas and Mining | 1.24 | .844 | 1.82 |
| Manufacturing, Durable | 1.2* | 1.05 | 1.38 |
| Transportation, Communication and Utilities | .937 | .81 | 1.07 |
| Retail | .949 | .733 | 1.22 |
| Finance, Insurance and Real estate | 1.20* | 1.03 | 1.41 |
| North East | .904 | .772 | 1.05 |
| North Central | .918 | .812 | 1.03 |
| West | .794* | .705 | .89 |
| 0 – 17 years | .013* | .010 | .02 |
| 18 - 34 years | .310* | .265 | .36 |
| 45 - 54 years | .981 | .848 | 1.13 |
| 55 - 64 years | .736* | .638 | .85 |
| Log(Total Cost) | .718* | .688 | .75 |

*Legend.* Table 5. Multinomial Logit Regression of Body Regions of Neck (Cervical), Upper Back (Thoracic), and Lower Back (Lumbar) Adjusting for Age, Gender, Geographic, and Industry Variables – Inpatient Analysis: The table presents the Relative Risk Ratios and confidence interval estimates for the inpatient data evaluated from the Medstat database, as described in the methods. Body regions are described in the methods. The referent group is female, age 35-44, works in the manufacturing/non-durable goods sector, and resides in the southern region of the US. The asterisks (*) signify the statistically significant outputs.

In the inpatient data (Table 5), increased relative risk ratios were found for males in all three body regions examined [neck: RRR = 1.95 (95% CI = 1.71, 2.22); upper back: RRR = 1.88 (95% CI = 1.56, 2.26); and lower back: RRR = 2.12 (95% CI = 1.92, 2.34)].

Geographic location in the north or west is associated with fewer neck related diagnoses, and location in the west was protective compared to the referent group for lower back diagnoses. Age less than 34 or age 55-64 was associated with fewer neck and lower back diagnoses, as was age less than 34 with upper back.

Finance, insurance, and real estate workers had significantly more neck and lower back diagnoses than workers in the manufacturing of durable goods who had lower rates of back diagnoses. Retail workers had fewer thoracic diagnoses compared to the referent group consisting of female, age 35 – 44 years. The logarithm of cost variable indicated that the referent group was less likely to have higher costs than males in the inpatient admissions data with respect to neck and lower back diagnoses.

In the outpatient data (Table 6), increased relative risk ratios were found for males in all three body regions examined [neck: relative risk ratio (RRR) = 1.27 (95% Confidence Interval (CI) = 1.25, 1.28); upper back: RRR = 1.57 (95% CI = 1.55, 1.59); and lower back: RRR = 1.85 (95% CI = 1.83, 1.87)]. Geographic locations in the north or west were associated with more neck and upper back related diagnoses.

Age less than 34 or greater than 45 was associated with fewer neck and upper back diagnoses. In the lower back, increased RRRs were found for all industries except for transportation/communication/utilities and finance/insurance/real estate workers.

In the lower back, more lumbar diagnoses were associated with northcentral geographic location and age between 45 and 54, while age below 34 was associated with fewer lumbar diagnoses, and age 55-64 was not significantly different from the referent group. The logarithm of cost variable indicated that the referent group was less likely to have higher costs than males in the outpatient services data.

**Table 6. Multinomial Logit Regression of Body Regions of Neck (Cervical), Upper Back (Thoracic), and Lower Back (Lumbar) Adjusting for Age, Gender, Geographic, and Industry Variables – Outpatient Analysis**

| Effect | Odds Ratio | 95% Wald | |
|---|---|---|---|
| | Point Estimate | Confidence Limits | |
| Neck Body Region | | | |
| Male | 1.27* | 1.25 | 1.28 |
| Oil, Gas and Mining | .67* | .63 | .71 |
| Manufacturing, Durable | .76* | .75 | .77 |
| Transportation, Communication and Utilities | .634* | .62 | .64 |
| Retail | .625* | .59 | .65 |
| Finance, Insurance and Real estate | .601* | .58 | .61 |
| North East | 1.38* | 1.34 | 1.4 |
| North Central | 6.10* | 6.0 | 6.20 |
| West | 1.25* | 1.23 | 1.28 |
| 0 – 17 years | .8* | .08 | .08 |
| 18 - 34 years | .55* | .54 | .56 |
| 45 - 54 years | .94* | .92 | .96 |
| 55 - 64 years | .66* | .65 | .68 |
| Log(Total Cost) | 1.07* | 1.07 | 1.08 |
| Upper Back Body Region | | | |
| Male | 1.57* | 1.55 | 1.59 |
| Oil, Gas and Mining | .90* | .85 | .96 |
| Manufacturing, Durable | .700* | .69 | .72 |
| Transportation, Communication and Utilities | .92* | .90 | .94 |
| Retail | .68* | .65 | .72 |
| Finance, Insurance and Real estate | .66* | .65 | .68 |
| North East | 1.08* | 1.06 | 1.11 |

**Table 6. (Continued)**

| Effect | Odds Ratio | 95% Wald | |
|---|---|---|---|
| | Point Estimate | Confidence Limits | |
| North Central | 3.09* | 3.03 | 3.14 |
| West | 1.44* | 1.42 | 1.47 |
| 0 – 17 years | .08* | .08 | .08 |
| 18 - 34 years | .67* | .65 | .68 |
| 45 - 54 years | .92* | .89 | .94 |
| 55 - 64 years | .72* | .71 | .74 |
| Log(Total Cost) | 1.07* | 1.07 | 1.08 |
| Lower Back Body Region | | | |
| Male | 1.85* | 1.83 | 1.87 |
| Oil, Gas and Mining | 1.14* | 1.10 | 1.1 |
| Manufacturing, Durable | 1.04* | 1.03 | 1.05 |
| Transportation, Communication and Utilities | 1.0* | 1.00 | 1.03 |
| Retail | 1.07* | 1.05 | 1.11 |
| Finance, Insurance and Real estate | .94* | .93 | .958 |
| North East | .935* | .92 | .95 |
| North Central | 1.56* | 1.54 | 1.58 |
| West | .80* | .79 | .81 |
| 0 – 17 years | .02* | .02 | .02 |
| 18 - 34 years | .45* | .45 | .46 |
| 45 - 54 years | 1.08* | 1.06 | 1.10 |
| 55 - 64 years | 1.01* | .99 | 1.03 |
| Log(Total Cost) | 1.07* | 1.07 | 1.08 |

*Legend.* Table 6: Multinomial Logit Regression of Body Regions of Neck (Cervical), Upper Back (Thoracic), and Lower Back (Lumbar) Adjusting for Age, Gender, Geographic, and Industry Variables – Outpatient Analysis: The table presents the Relative Risk Ratios and confidence interval estimates for the outpatient data evaluated from the Medstat database, as described in the methods. Body regions are described in the methods. The referent group is female, age 35-44, works in the manufacturing/non-durable goods sector, and resides in the southern region of the US. The asterisks (*) signify the statistically significant outputs.

# Discussion

Average costs per person among the three body regions of focus in this analysis were found to be highest for upper back in the inpatient data and for lower back in the outpatient data. Approximately half (25 out of 47) ICD-9 codes with the highest average costs per person in the inpatient data consisted of intervertebral disc, spinal stenosis, and scoliosis codes. Of the outpatient service records examined, 23 out of 50 codes were for intervertebral disc, spinal curvature, and spinal stenosis diagnoses. The highest average costs among the DRG codes were those related to spinal fusion, and among procedural codes those related to implantable devices (e.g. generators and neurostimulators). Regression analysis across body regions, accounting for demographic, work, and total cost variables, revealed several key findings. Evaluation based on extraction of records of inpatient and outpatient data suggests that males have greater risk ratios for diagnoses in all three body regions examined. This might be due, for example, to greater exposure of males to hazardous environments, in comparison to females, causing higher MSD, although the current analysis does not allow definitive determination of cause. Geographic location had a range of effects on risk for cervical, thoracic, and lumbar diagnoses. There were fewer significant effects of industry type in the inpatient data. The effects of industry reflects decreased risk ratios relative to the manufacturing non-durable goods sector in the outpatient data. Average costs were greater for the referent group in the inpatient data for neck and lower back, but were decreased for the referent group in the outpatient data across all three body regions.

The outcomes obtained differ between the inpatient and outpatient claims. The outpatient claims analysis signifies that employees residing in the north central part are more likely to have MSD. MSD in lower back regions are more prevalent among those employed in the retail trade sector. The inpatient medical claims analysis suggests that male individuals are more likely to have MSD, and that those employed in the oil, gas and mining industry are more likely to have neck and lower back related medical claims and those in the age group of 45 to 54 years are more likely to have neck and upper back related MSD. The analysis of medical costs in administrative databases related to MSD classified by ICD-9, DRG and procedure codes are less well-developed in the literature. This study contributes to the literature of medical costs of MSD focusing on different medical cost components as well as demographic factors. The use of a medical claims dataset has certain advantages and

challenges. Conclusions drawn from analysis of this data potentially have more generalizability due to the broader demographic characteristics of the data set, particularly with respect to geographic location and age. Examination of employed individuals may increase the relevance of the findings for working populations. Such data sets, however, also are subject to significant oversight and management to ensure integrity of the data (Thompson Reuters, 2010). Claims data, however, present challenges with respect to ascertainment of diagnostic and procedural codes used for data selection and analysis (Clement et al, 2013; Benchimol et al., 2011). In particular, the use of ICD-9 and other diagnostic and procedural codes to select cases for analysis of health impacts and costs requires, ideally, the use of validated codes. The availability of validated codes would potentially mitigate the risk for selection bias that could influence results. Validation could be by methods such as multiple researchers independently selecting codes to best choose cases, with a consensus built from such exercises and adequate statistical analysis of reproducibility (Walraven et al., 2012) or the use of published codes combined from previous studies that may have a published literature supporting the accuracy of such codes to correctly select cases, a "referenced" set of identifying codes (Sinnot et al., 2012).

Future considerations include methodologic and hypothesis related developments including a broader range of outcomes, wage replacement payments, days away from work and a broader range of MSD conditions. Differences due to identification of records by ICD-9 codes or other codes as well as differences in health care access/utilization, versus differences due to prevalence/incidence of different diagnoses, are both potential explanations for findings in studies of health effects and costs in administrative databases. Improved methods of selecting cases, for example, that include ICD-9, DRG and procedural codes, as well as other markers of diagnosis, may address some of this issue. Using validated or referenced versus non-validated or non-referenced codes to examine datasets and extract records for analyses may also be important to understand variables related to MSD and associated costs. Use of a variable such as body region, as utilized in this analysis, requires further evaluation as a method of classifying data to compare factors associated with MSD and costs. The role of variables such as industry type and geographic location also require further evaluation, along with standard demographic variables such as age and gender. Such methods development would contribute to improved analyses of MSD related health effects, industry and other characteristics, and costs in administrative databases, and allow for more refined evaluation of issues specific to employed individuals with MSD.

# Appendix – A
# Average Costs by ICD-9 Codes, Body Regions– Inpatient Admissions

| ICD-9 | Diagnosis | Body Region | N | Minimum Cost | Maximum Cost | Average Cost |
|---|---|---|---|---|---|---|
| 73712 | Kyphosis postlaminectomy | Nonspecific | 7 | 45,416 | 216,767 | 92,222 |
| 72401 | Spinal stenosis of thoracic region | Upper Back (Thoracic) | 78 | 360 | 572,162 | 88,498 |
| 72251 | Degeneration of thoracic or thoracolumbar intervertebral disce | Upper Back (Thoracic) | 137 | 926 | 1,264,538 | 86,124 |
| 72141 | Spondylosis with myelopathy thoracic region | Upper Back (Thoracic) | 35 | 2,885 | 357,910 | 85,029 |
| 72270 | Intervertebral disc disorder with myelopathy unspecified region | Nonspecific | 13 | 9,608 | 566,675 | 73,061 |
| 72292 | Other and unspecified disc disorder of thoracic region | Upper Back (Thoracic) | 53 | 2,786 | 398,153 | 70,347 |
| 72402 | Spinal stenosis, lumbar region, without neurogenic claudication | Lower Back (Lumbar) | 4791 | 9 | 1,461,554 | 67,680 |
| 73742 | Lordosis associated with other conditions | Lower Back (Lumbar) | 6 | 10,231 | 150,661 | 63,898 |
| 72283 | Postlaminectomy syndrome of lumbar region | Lower Back (Lumbar) | 422 | 1,032 | 660,350 | 63,154 |
| 72252 | Degeneration of lumbar or lumbosacral intervertebral disc | Lower Back (Lumbar) | 3183 | - | 937,716 | 59,709 |
| 72293 | Other unspecified disc disorder of lumbar region | Lower Back (Lumbar) | 597 | 300 | 712,957 | 58,713 |
| 72271 | Intervertebral disc disorder with myelopathy cervical region | Neck (Cervical) | 1192 | 1,116 | 932,630 | 58,708 |
| 72273 | Intervertebral disc disorder with myelopathy lumbar region | Lower Back (Lumbar) | 372 | 43 | 709,015 | 58,518 |

## Appendix A. (Continued)

| ICD-9 | Diagnosis | Body Region | N | Minimum Cost | Maximum Cost | Average Cost |
|---|---|---|---|---|---|---|
| 72211 | Displacement of thoracic intervertebral disc without myelopathy | Upper Back (Thoracic) | 160 | 175 | 800,480 | 56,299 |
| 72142 | Spondylosis with myelopathy lumbar region | Lower Back (Lumbar) | 48 | 2,708 | 207,947 | 54,159 |
| 72281 | Postlaminectomy syndrome of cervical region | Neck (Cervical) | 67 | 2,847 | 302,876 | 53,636 |
| 72291 | Other and unspecified disc disorder of cervical region | Neck (Cervical) | 507 | 801 | 1,491,176 | 53,380 |
| 72290 | Other and unspecified disc disorder of unspecified region | Nonspecific | 117 | 514 | 406,428 | 52,702 |
| 72280 | Postlaminectomy syndrome of unspecified region | Nonspecific | 25 | 1,315 | 368,321 | 52,026 |
| 83920 | Closed dislocation lumbar vertebra | Lower Back (Lumbar) | 44 | 5,725 | 313,470 | 48,046 |
| 72190 | Spondylosis of unspecified site without myelopathy | Nonspecific | 176 | 744 | 353,982 | 43,062 |
| 30789 | Other, pain disorder related to psychological factors | Nonspecific | 102 | 1,478 | 379,920 | 36,411 |
| 72210 | Displacement of lumbar intervertebral disc without myelopathy | Lower Back (Lumbar) | 3356 | - | 843,837 | 32,850 |
| 73720 | Lordosis (acquired) (postural) | Nonspecific | 39 | 4,292 | 292,245 | 32,497 |
| 72479 | Other disorders of coccyx | Lower Back (Lumbar) | 53 | 774 | 222,827 | 29,348 |
| 72232 | Schmorl's nodes of lumbar region | Upper Back (Thoracic) | 7 | 2,173 | 66,102 | 24,754 |
| 72231 | Schmorl's nodes of thoracic region | Neck (Cervical) | 6 | 6,655 | 29,877 | 17,091 |

# Appendix – B
# Average Costs by ICD-9 Codes, Body Regions– Outpatient Services

| ICD-9 | Diagnosis | Body Region | N | Minimum Cost | Maximum Cost | Average Cost |
|---|---|---|---|---|---|---|
| 72252 | Degeneration of lumbar or lumbosacral intervertebral disc | Lower Back (Lumbar) | 492565 | 0 | 290361 | 341.421 |
| 72281 | Postlaminectomy syndrome of cervical region | Neck (Cervical) | 15181 | 0 | 100555 | 337.6902 |
| 73719 | Other kyphosis acquired | Nonspecific | 717 | 0 | 17572.65 | 329.6016 |
| 72273 | Intervertebral disc disorder with myelopathy lumbar region | Lower Back (Lumbar) | 37048 | 0 | 72777.89 | 319.6333 |
| 72251 | Degeneration of thoracic or thoracolumbar intervertebral disc | Upper Back (Thoracic) | 27616 | 0 | 71394.88 | 306.6784 |
| 73739 | Other kyphosis and scoliosis | Nonspecific | 11152 | 0 | 162632 | 300.2871 |
| 73720 | Lordosis (acquired) (postural) | Nonspecific | 4104 | 0 | 34316.58 | 299.6638 |
| 73729 | Other lordosis acquired | Nonspecific | 678 | 0 | 7910 | 293.3985 |
| 83931 | Open dislocation thoracic vertebra | Lower Back (Lumbar) | 60 | 0 | 3071.729 | 289.9596 |
| 83912 | Open dislocation second cervical vertebra | Neck (Cervical) | 27 | 5.309998 | 4020.838 | 281.6054 |
| 72142 | Spondylosis with myelopathy lumbar region | Lower Back (Lumbar) | 9744 | 0 | 77088.5 | 280.4011 |
| 73710 | Kyphosis (acquired) (postural) | Nonspecific | 18260 | 0 | 72799.98 | 268.5505 |
| 72290 | Other and unspecified disc disorder of unspecified region | Nonspecific | 7744 | 0 | 59491.5 | 244.0819 |
| 72230 | Schmorl's nodes of unspecified region | Nonspecific | 308 | 0 | 2816.578 | 242.9027 |
| 30789 | Other, pain disorder related to psychological factors | Nonspecific | 6471 | 0 | 12997.27 | 237.9031 |

## Appendix B. (Continued)

| ICD-9 | Diagnosis | Body Region | N | Minimum Cost | Maximum Cost | Average Cost |
|---|---|---|---|---|---|---|
| 72270 | Intervertebral disc disorder with myelopathy unspecified region | Nonspecific | 1498 | 0 | 18592.73 | 235.9477 |
| 73730 | Scoliosis (and kyphyscoliosis) idiopathic | Nonspecific | 149902 | 0 | 217747.8 | 234.9686 |
| 73743 | Scoliosis associated with other conditions | Nonspecific | 7691 | 0 | 172250.1 | 221.6174 |
| 83930 | Open dislocation lumbar vertebra | Upper Back (Thoracic) | 251 | 0 | 3967.958 | 217.7314 |
| 73734 | Thoracogenic scoliosis | Upper Back (Thoracic) | 2889 | 0 | 19934.72 | 215.9835 |
| 83904 | Closed dislocation of fourth cervical vertebra | Neck (Cervical) | 3788 | 0 | 23953.47 | 214.7471 |
| 72190 | Spondylosis of unspecified site without myelopathy | Nonspecific | 27533 | 0 | 112565.3 | 213.4298 |
| 83921 | Closed dislocation thoracic vertebra | Upper Back (Thoracic) | 67470 | 0 | 45632.25 | 212.4443 |
| 83902 | Closed dislocation second cervical vertebra | Neck (Cervical) | 11014 | 0 | 36338.25 | 208.0394 |
| 83907 | Closed dislocation seventh cervical vertebra | Neck (Cervical) | 4870 | 0 | 114899.1 | 204.4013 |
| 83903 | Closed dislocation third cervical vertebra | Neck (Cervical) | 2379 | 0 | 10254 | 203.0481 |
| 83906 | Closed dislocation sixth cervical vertebra | Neck (Cervical) | 8089 | 0 | 47037.45 | 201.7781 |
| 73740 | Unspecified curvature of spine associated with other conditions | Nonspecific | 684 | 0 | 12500 | 200.1613 |
| 83905 | Closed dislocation fifth cervical vertebra | Neck (Cervical) | 15306 | 0 | 6400 | 196.6267 |
| 83901 | Closed dislocation of first cervical vertebra | Neck (Cervical) | 18353 | 0 | 5500 | 195.8997 |

*Legend:* Appendix A and B. Average Costs by ICD-9 Codes, Body Regions. The next 30 ICD-9 codes (21 - 50) with the highest average costs per person following Tables 3a and 3b are presented with inpatient data in Appendix A and outpatient data in Appendix B.

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