Early Advanced Imaging among Washington State Workers' Compensation Claimants with Non-Specific Acute Occupational Low Back Pain: An Evaluation of Precursors, Costs, Utilization, and Outcomes

Janessa M. Graves

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This is to certify that I have examined this copy of a doctoral dissertation by

Janessa M. Graves

and have found that it is complete and satisfactory in all respects,
and that any and all revisions required by the final
examining committee have been made.

Chair of the Supervisory Committee:

Jeffrey G. Jarvik

Reading Committee:

Jeffrey G. Jarvik

Gary M. Franklin

Deborah Fulton-Kehoe

Diane P. Martin

William E. Barlow

Date: 9/28/11

University of Washington

Abstract

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Janessa M. Graves

Chair of the Supervisory Committee:
Professor Jeffrey G. Jarvik
School of Medicine
Departments of Radiology and Neurological Surgery

Early use of advanced diagnostic imaging for non-specific, acute low back pain (LBP) is associated with increased healthcare utilization and costs, yet does not contribute to improved medical management or health outcomes for patients. Evidence-based guidelines recommend use of magnetic resonance imaging (MRI) within the first six weeks of symptoms for acute LBP only among patients with characteristics that may indicate neurological impairment or serious underlying conditions. Other patients should be treated conservatively, only receiving imaging if symptoms persist beyond six weeks. For workers' compensation programs, adherence to these guidelines is important to avoid mis- and overuse of imaging for LBP, which is a common and costly occupational condition. This dissertation describes three population-based, prospective cohort studies of workers' compensation claimants with acute occupational LBP in Washington State. The first study assessed the factors associated with receiving early MRI and found that

workers who were male or whose initial office visit was with a surgeon were more likely to receive early MRI. Workers with elevated work fear-avoidance, higher Roland scores, or increased injury severity were more likely to receive early imaging than counterparts with lower levels or scores. The second study evaluated the impact of early imaging on the utilization and cost of healthcare in the year following imaging. Results showed that workers with early MRI were less likely to have subsequent advanced imaging, more likely to have outpatient visits, and had higher adjusted mean costs for outpatient and inpatient care, disability compensation, and other workers' compensation expenses. The third study evaluated the effect of early imaging on health outcomes 1 year after imaging. Results showed that imaging was not associated with 1-year health outcomes but was associated with an increased likelihood of long-term disability for workers with mild/major sprains. Early MRI was associated with longer disability duration for all workers. Occupational LBP is a multi-factorial, complex condition. Early MRI plays an important role in its diagnosis, but inappropriate use may have deleterious consequences that could be avoided through adherence to evidence-based guidelines.

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Glossary

ACR	American College of Radiology
AHCPR	Agency for Health Care Policy and Research (now the Agency for Healthcare Research and Quality, AHRQ)
BMI	Body mass index
CI	Confidence interval
CPT(-4)	Current Procedural Terminology (v.4)
CT	Computed tomography
D-RISC	Disability Risk Identification Study Cohort
GLM	Generalized linear model(s)
HCA	Health Care Authority
HCPCS	Healthcare Common Procedure Coding System
HR	Hazard ratio
IRR	Incidence rate ratio
L&I	Labor and Industries (Washington State)
LBP	Low back pain
MRI	Magnetic resonance imaging
PET	Positron emission tomography
PT/OT	Physical therapy/Occupational therapy
RDQ	Roland-Morris Disability Questionnaire
RR	Relative risk
SD	Standard deviation
SF-36®	Short Form (36-Item) Health Survey

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Dedication

To my best friend and patient husband, Jim Graves, who has been proud and supportive of my work and has shared the uncertainties, challenges and sacrifices for completing this dissertation. You are my best cheerleader.

Chapter 1. Introduction

I. BACKGROUND AND SIGNIFICANCE

A. Low back pain

Low back pain (LBP) has profound and widespread social and economic impacts in the U.S. for individuals, employers, disability compensation groups, insurers, and the healthcare system. A combination of uncertainties in diagnosis and mismanagement of LBP contribute to costs associated with diagnosis and treatment and rising prevalence of chronic LBP.

LBP is the second most common cause of disability among U.S. adults, affecting approximately 80% of the adult population at some point in their lifetime.(1, 2) Occupational LBP, characterized by acute symptoms acquired while working, will affect 28% of the working population in their career.(3) This takes a considerable toll on the workforce; it is estimated that 10-20% of those sustaining an occupational low back injury do not return to the same level of work.(4) The Institute of Medicine lists LBP in the highest quartile of their top 100 priority areas for comparative effectiveness research.(5)

Patient history and physical examination generally classifies LBP into the following broad categories: nonspecific LBP, back pain potentially associated with radiculopathy or spinal stenosis, or back pain potentially associated with another specific spinal cause.(2) LBP is generally considered to have three clinical phases: acute, subacute, and chronic. Acute LBP is defined as LBP with a duration of less than 4 weeks for which a patient sought care.(6) Subacute LBP describes LBP of 4-12 weeks after symptom onset (7), and chronic LBP is persistent LBP of more than 3-6 months for which patients have received evaluation and unsuccessful treatment. In this paper, chronic LBP will be specified as such; otherwise, all references to LBP refer to the acute or subacute classifications.

Nationally, LBP accounts for up to $625 billion in direct and indirect costs in the U.S. labor and financial sectors.(2, 8) These costs include direct healthcare costs and resource consumption (3, 9, 10), reduced productivity or lost workdays (11-13), and compensation for disabled workers affected by occupational LBP.(14) Costs associated with care and disability compensation for LBP have grown unabatedly since as early as 1950.(15) Recent research provides evidence of a continued increase and the large scope of LBP diagnosis and treatment (16), suggesting that the increasing prevalence of LBP in the U.S. will likely continue.

B. Occupational LBP

A common reason for work disability (3, 13), LBP accounts for up to 40% of all lost workdays.(3) Researchers estimate that LBP leads to approximately 175 million workdays are lost per year and $20 billion in lost productivity.(17) The National Occupational Research Agenda recognizes this and lists low back disorders among its priority research areas due to the number of workers at risk, potential severity, and the probability that new information will help abate the hazard.(18) Because most workers attribute LBP to occupational exposures, LBP is a commonly a cited complaint in workers' compensation claims. In Washington State, the yearly rate of compensable back pain claims is 59.5 per 10,000 FTE, nearly three times that of any other work-related musculoskeletal disorder.(19) Nationally, it accounts for up to 30% of workers' compensation claims, which in turn constitute a disproportionately higher percentage of total workers' compensation costs.[4,5] For example, in Washington, back injuries constitute 18% of all claims and 23% of all workers' compensation costs (fiscal year 2010).(20)

Given the large proportion of missed work attributable to LBP (3) and substantial costs due to losses in productivity (17), the financial impact of LBP is considerable. Recent national figures for the costs associated with occupational LBP are not available, however, a 1999 study estimated that $8.8 billion was spent on LBP claims in 1995.(21) In Washington State, incurred workers' compensation costs for treatment of occupational injuries of all back exceeded $132 million for the fiscal year 2010.(20)

II. DIAGNOSIS AND TREATMENT OF LBP

A. Diagnosis

LBP is the fifth most common reason for seeking out a primary care physician, the entry point of the non-emergent healthcare system.(22) Among LBP patients in primary care, over 85% have pain that cannot be reliably attributed to a specific disease or spinal abnormality and are therefore diagnosed with nonspecific or idiopathic LBP. Only a small percentage of patients seeking care for LBP have a specified diagnosis, and these are often complex, serious conditions: compression fracture (4%), spinal stenosis or symptomatic herniated disc (3-4%) and ankylosing spondylitis (0.3-5%).(2)

LBP is a symptom that may result from a host of causes; it is not a specific disease. Providing a definite diagnosis for LBP is challenging, because it is neither anatomically nor histologically characterized, except in the small fraction of patients with an identifiable underlying cause. Further, a single case of LBP may be characterized with several different diagnoses, each with different treatment plans.

Physicians rely on a comprehensive history and physical examination, including neurologic evaluation, to identify the small percentage of patients who may have serious underlying conditions (e.g. anklyosing spondylitis). Research suggests that most (80-90%) episodes of non-specific LBP spontaneously resolve within 6 weeks of injury, irrespective of treatment utilization or modality (23, 24), so it is generally recommended that immediate diagnostic studies are reserved until after 6 weeks.

Diagnostic imaging may not reliably identify a specific attribution or disease, without a reference standard that indicates the presence of abnormalities with and without symptoms.(25-27) Plain-film radiographs are difficult to interpret and have a high rate of false positive results, and are therefore not recommended in as diagnostic tools for LBP.(28, 29) Computerized tomography (CT) scans provide complementary information to other imaging, especially in the diagnosis of tumors, fractures, dislocations, or osteoarthritis.(29) However, disadvantages of CT includes exposure to radiation, less detailed images, and a high percentage of false positives.(29) Magnetic resonance imaging (MRI) is used most often for imaging neurologic structures of the back. Its principle advantage is the ability to provide detailed images of soft tissue structures and diagnose early osteomyelitis, discitis, epidural-type infections, or hematomas.(29) MRI also has relatively low specificity (82%) and provides equivocal evidence of structural anomalies that could be attributable to acute and subacute LBP in the first 12 months of symptoms.(30, 31)

Low specificity, or the inability of a test to correctly identify individuals who do not have a condition, may lead to misclassification of diagnoses. Positive findings may be observed in asymptomatic patients (low specificity), and negative findings may be observed in patients experiencing LBP (low sensitivity). Studies have described a weak correlation between lumbar imaging studies and clinical symptoms.(32, 33) Due to the chance of misclassification, findings, whether positive or negative, may be questioned because they could falsely reflect the true source of the pain.(34) CT or MRI studies may be helpful in the diagnosis of patients with suspected infection or neoplasm, or when imaging of soft tissue is necessary for further treatment (e.g. surgery).(28) In most cases, however, research strongly advises against the use of routine diagnostic imaging tests in the first 4-6 weeks of LBP (2, 35), and when imaging is used, results should be correlated with findings from physical examination and patient history.(29)

Other than physical exam and diagnostic imaging, other diagnostic tools include laboratory testing, electrophysiologic evaluation, bone scintigraphy, discography, and myelography. Laboratory tests are useful and recommended when infection is suspected.(28) Electrophysiologic tests, such as nerve-conduction studies, may be helpful in identifying the location of the nerve root to diagnosis peripheral neuropathy from radiculopathy or myopathy (28) and are generally not useful (though sometimes required by workers' compensation claims).(30) Bone scintigraphy may be used to identify osteomyelitis, bony neoplasm or occult fracture, but only when clinical findings suggest these conditions and plain film radiographs are negative. Discography and myelography are relatively invasive and not recommended in most acute LBP cases.(30)

B. Treatment and outcomes

While treatments for acute LBP have proliferated over time, their epidemiologic validity or effectiveness remains equivocal. A thorough physical exam and patient history are appropriate for all initial LBP visits and advanced imaging is suggested for patients with severe or progressive neurologic deficits or when serious underlying conditions are suspected.(2) After diagnosis, treatment for acute LBP can be divided into two categories, primary and secondary treatment, which reflect the degree of injury severity experienced by the patient.

For acute LBP patients who do not present signs of serious neurological symptoms, primary treatment LBP should include palliative and educational measures in the first 4-6 weeks of symptoms. Primary conservative management is encouraged. A recent review of LBP clinical practice guidelines emphasized staying active, education about LBP, acetaminophen, nonsteriodal anti-inflammatory drugs, spinal manipulation therapy (SMT), reassurance, muscle relaxants and weak opioid analgesics.(8) However, the effectiveness of these treatments has been called into question: with SMT, short-term benefits may mask long-term ineffectiveness. Bed rest, back exercises, corsets, acupuncture, and other alternatives demonstrate limited effectiveness compared to conventional treatments and are not recommended.(8, 36)

For severe acute LBP with substantial neurological symptoms, such as cauda equina syndrome, secondary treatment with advanced imaging is recommended. These patients, especially those exhibiting less serious symptoms, should receive conservative primary treatment as well.(8) Secondary management of acute LBP includes epidural steroid injections, multidisciplinary rehabilitation, behavioral therapy, and decompression surgery. For patients with unresolved LPB, these approaches should only follow after observing no improvement with conservative management, however, guidance on how to define and identify "unsuccessful" conservative management is unclear.(8)

Despite outlines and recommendations for treatment, strong evidence for effectiveness and adherence is lacking (37-39) and guidelines are generally not followed.(39) The stakes are high – ineffectively treated acute LBP patients may become recurrent or chronic LBP patients. It has been reported that 62% of patients experience recurrent episodes of LBP (40), 33% experience recurrent work absence (40), and 34% seek care for recurrent LBP.(41) Recurrence is associated with increased likelihood of accruing work disability and medical and indemnity costs.(41)

Persistent pain and disability from chronic LBP is also common; 42-75% of individuals experience pain a year after injury.(40) Chronic LBP may be easier to prevent than treat, which is especially important because associated healthcare costs can be considerable. Recent rises in healthcare costs for LBP have been attributed to chronic cases.(1) This is doubly concerning because of the increasing prevalence of chronic LBP; the overall prevalence of chronic LBP rose 162% from 1992 to 2006.(1)

C. Evidence-based guidelines

LBP is a commonly seen complaint in the primary care population, and physicians are responsible for identifying the few whose symptoms warrant further evaluation. Seasoned clinicians may be able to act on intuition after a lifetime of experience, but developing that eye to identify suspicious, more serious problems is challenging. Whether by intuition or induction, recognition of symptoms that must be investigated further is essential. Appropriateness Criteria, developed by the American College of Radiology (ACR) in 1996, intend to guide referring physicians and radiologists in this process of making decisions for future imaging and referral.(42) Termed "red flags," Table 1.1 lists symptoms indicative of more complicated status that should be investigated using diagnostic testing.

Table 1.1: Low back pain "red flags" warranting further investigation

Recent significant trauma, or milder trauma (if age ≥50)
Unexplained weight loss
Unexplained fever
Immunosuppression
History of cancer
IV drug use
Prolonged use of corticosteroids, osteoporosis
Age (under 20 or over 70 years old)
Focal neurologic deficit progressive or disabling symptoms
Duration greater than 6 weeks.(42, 43)

In high-risk cases with suspected fractures, recommendations encourage radiography, and for patients with severe and/or progressive neurological deficits or serious underlying conditions, advanced imaging is recommended. According to AHCPR guidelines, MRI is warranted within the first month of symptoms for red-flagged patients.(44) MRI's diagnostic accuracy of soft tissue contributes to its improved diagnostic capability for conditions such as disc degeneration, spinal stenosis, infection, and other serious conditions.(45) MRI is acceptable for patients with persistent LBP and radicular pain only if patients are candidates for future treatment or intervention.(46) Radiculopathy alone, however, is not considered a red flag symptom by most international standards.(46) CT is the preferred modality of choice for the evaluation of symptoms associated with bony structures, such as fractures. However, radiation exposure attributed to CT discourages its use. Because MRI can better evaluate marrow and soft tissue, it may be preferred over CT.

Impressive advancements in technology and radiological research have resulted in a rapid increase in the use of advanced diagnostic imaging in the last decade.(47, 48)

According to a recently released report of the nation's healthcare, the number of visits to physician offices and hospital outpatient departments during which MRI, computed tomography (CT), or positron emission tomography (PET) scans were ordered or provided increased three-fold between 1996 and 2007.(49)

Imaging of the lumbar spine is the most common form of diagnostic imaging for workers' compensation claims for all conditions: From 1996 to 2002, the national use of complex diagnostic testing among workers' compensation claimants rose 57%.(50) LBP imaging alone constituted over 62% ($7.4 million) of all Washington State workers' compensation advanced imaging costs in 2008.(51) As one of the primary drivers of costs in the workers' compensation system, use of advanced imaging for LBP is a primary concern of policy-makers in Washington State.

D. Early imaging

For decades, research has suggested that most (80-90%) episodes of LBP are resolved within six weeks of injury, irrespective of treatment utilization or modality.(23, 24) Accordingly, clinical practice guidelines for LBP maintain that for non-medically emergent red-flagged patients, routine spinal imaging tests are generally not necessary during the first month of symptoms.(2, 44, 52, 53) Despite clinical practice guidelines, the use of MRI for patients without red flag symptoms is increasing.(54) Overuse of inappropriate imaging should be avoided, because it is neither cost-effective (55) nor effective in providing evidence to guide subsequent treatment.(8) Indeed, routine, early imaging is not associated with improved clinical outcomes among individuals with nonspecific LBP.(33, 56, 57)

Clinical red flags, which indicate more severe injury and justify early imaging, include suspicion or evidence of infection, history of cancer, IV drug use, prolonged use of corticosteroids, osteoporosis, age over 70, or focal neurologic deficit with progressive or disabling symptoms.(44) For these patients, early use of MRI or CT may provide information necessary to identify severe, potentially dangerous conditions.

Research from the US and UK suggests that use of MRI within the first six weeks of symptoms in the absence of red flags (hereby referred to as *early MRI*) may be associated with increased treatment and costs, but not improved outcomes.(56, 58) Inappropriate early imaging may herald faster progression through the healthcare system, leading a patient to receive more healthcare than an his/her equivalent did not receive early imaging.(59) Early MRI may also have a deleterious psychological impact resulting from labeling a patient with a disease or diagnosis.(33)

Literature evaluating the use of early imaging for LBP is relatively limited. Two randomized controlled trials compared early MRI to radiographs or usual care.(56, 58, 60) Both studies conclude that early imaging is not unambiguously preferred compared to the alternative strategy. Further, authors from both studies expressed concerns for the marginal gains in health early imaging may provide at appreciable expense. Beyond these trials, early imaging has been associated with negative psychological impacts, without providing additional benefit of improved outcomes or diagnostic ability.(33)

These trials aim to generalize to the general population and not workers' compensation claimants, who may have distinctively different pain or needs.(25) Few studies have focused on the impact of early imaging in the worker population, yet given the increasing costs faced by payers (including workers' compensation funds), it is important to evaluate how this potentially inappropriate use of MRI for occupational LBP may contribute to healthcare costs and worker health outcomes. In a recent study of national workers' compensation claimant records, Webster and colleagues examined characteristics of patients who underwent early MRI and investigated subsequent outcomes such as disability duration, medical costs, and surgery. Results show that 22% of patients received early MRI, and authors concluded that for the majority of cases, there was limited indication of necessity for an early MRI, suggesting overutilization of this technology.(61)

Within the Washington State workers' compensation population, it is prudent to consider the economic and clinical consequences of early, non-indicated MRI use, especially given the current rise in healthcare costs and economic concerns of healthcare overutilization. Recent Washington State imaging management legislation instituted guidelines to limit unnecessary advanced imaging use, including MRI, computerized tomography, and positron emission tomography.(62) Further research is warranted to address the uncertainty associated with the diagnosis and treatment of LBP.

This dissertation research seeks to evaluate the impact of early imaging in three distinct projects. The first project will determine patient, work, injury, and provider characteristics that are significantly associated with a worker receiving MRI within the first 6 weeks of the onset of LBP (Chapter 2). Building upon the first project, the second will determine how healthcare utilization and costs differ according to whether a patient receives early imaging or not (Chapter 3). The final study addresses the changes in health and disability over one year among workers who received early MRI and those whose imaging was consistent with guidelines (Chapter 4).

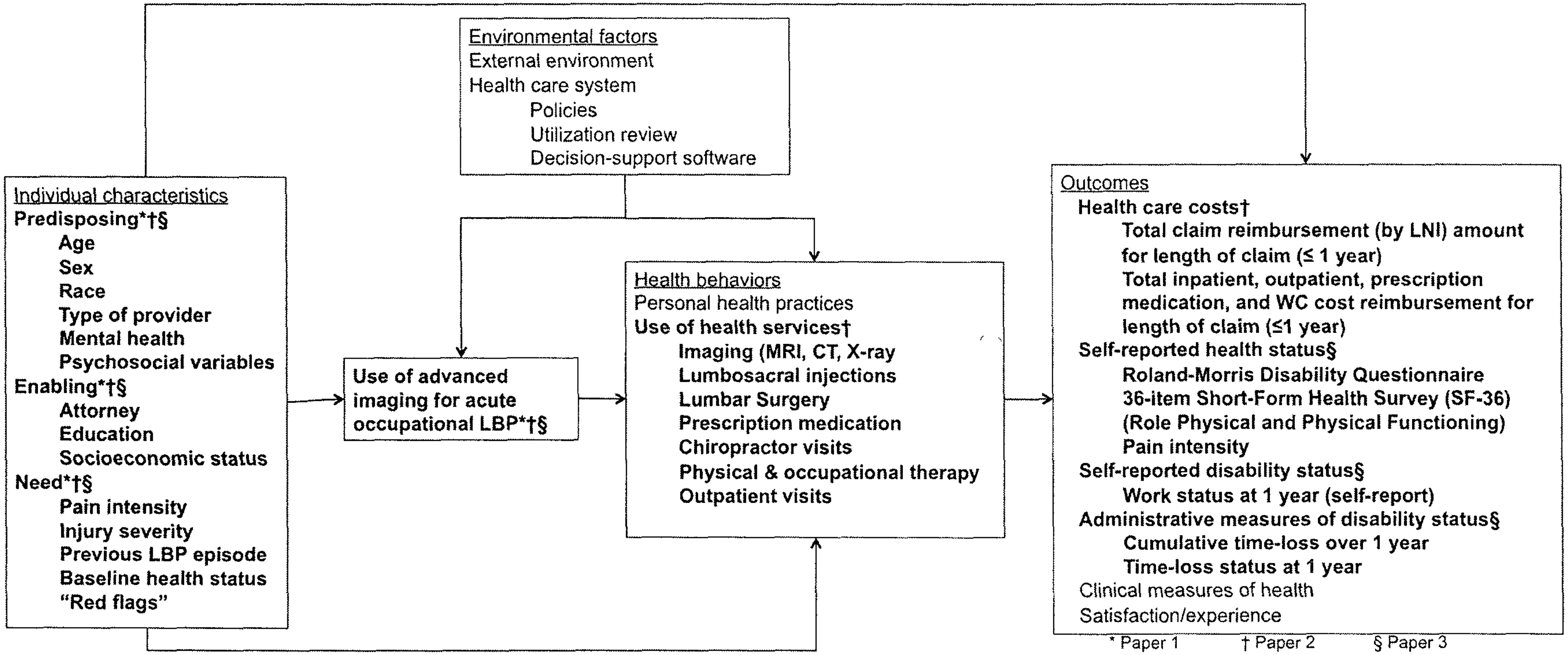
III. DISSERTATION CONCEPTUAL MODEL

The conceptual model for this dissertation is structured primarily around the relationship between occupational injury, diagnostic imaging, healthcare utilization, and recovery (Figure 1.1). This model is primarily structured after the Andersen-Newman Behavioral Model of Health Services Utilization and informed by the model of work and health by Lipscomb et al.(63, 64) In the Andersen-Newman model, population characteristics (predisposing, enabling, and need) affect an individual's health and healthcare utilization.(63) The Lipscomb model provides a general background and understanding of the relationships between injury, exposures, sequeale, and health policy.(64)

The conceptual model shown in Figure 1.1. describes healthcare utilization and costs as the products of individual characteristics, environmental factors, and health behaviors. Individual characteristics, as derived from the Andersen-Newman model, include "predisposing characteristics", such as demographics, which contribute to the likelihood that one will use or need healthcare. Personal "enabling characteristics" include resources that contribute to an individual's means and "know-how" to obtain and make use of services. "Need characteristics" includes perceived and evaluated need. Perceived need refers to how an individual views his/her own health and, in these studies, includes self-reported health, pain, disability, and functional status. Evaluated need represents professional judgment on a person's condition and their need for healthcare. In these studies, evaluated need characteristics include injury severity (evaluated through medical chart review), which also provides information regarding the presence of red flags. A previous, compensable LBP episode is also indicative of evaluated need.(63) In the conceptual model, environmental factors refer to elements of the external environment and healthcare system, that may influence the use of healthcare. For this research, these include policies implemented by workers' compensation programs, such as utilization review for advanced imaging use. Health behaviors include personal health practices and the use of health services, which is one outcome of interest for this dissertation research. Finally, outcomes associated with healthcare utilization include costs, perceived health status, disability status, evaluated health status (clinical measures), and the healthcare quality. For this dissertation, outcomes of interest include costs, self-reported/perceived health status, and disability measures.

The conceptual model structure is divided into separate focal areas representing the three dissertation papers, each of which are described in the sections below. The focus of the first paper is how predisposing, enabling, and need factors influence the use of health services – namely early MRI for LBP. The focus of the second paper is to evaluate health utilization and costs associated with the use of early MRI (adjusting for individual characteristics). The third paper evaluates the effect of early imaging on health and disability measures one year after injury, adjusting for baseline health and disability as well as patient characteristics.

Figure 1.1: Dissertation conceptual model. Elements contributing to the broad focus of the dissertation are shown in bold. Associations relevant to specific papers are noted with symbols (* Paper 1; † Paper 2; § Paper 3.)



IV. SPECIFIC AIMS

This dissertation consists of 3 papers, all of which utilize data obtained from the Washington Workers' Compensation Disability Risk Identification Study Cohort (D-RISC), a population-based study designed to identify risk factors for chronic disability among workers with acute back injury.(65-67) Information about recruitment for the D-RISC study can be found in Appendix I.

The specific aims of this dissertation are as follows:

Factors associated with early MRI.

1. To evaluate associations between receiving early MRI and demographic, clinical, physician, and work-related factors.

Costs and Utilization

1. To evaluate the associations between healthcare utilization and receipt of early imaging. Utilization measures include the following:
    a. Likelihood of receiving at least one outpatient visit, PT/OT visit, chiropractic visit, lumbar surgery, lumbosacral injection, and lumbar imaging (CT, MRI, radiograph) in the year following low back injury.
    b. Relative difference in the number of visits (outpatient, PT/OT, chiropractor) or procedures (surgery, injections, imaging) in the year following low back injury.
2. To estimate the association between receiving early imaging and outpatient visits, office visits for PT/OT or chiropractic care, lumbar surgery, lumbosacral injections, and lumbar imaging in the year following low back injury.

3. To estimate the impact of early imaging on outpatient, inpatient, pharmacy, and workers' compensation costs in the year following low back injury.
4. To estimate the impact of early imaging on disability compensation expenditures in the year following low back injury.

Health and Disability Outcomes.

1. To evaluate associations between receiving early imaging and the following health outcomes one year after injury: self-reported pain intensity, SF-36 role physical and physical functioning scores, and Roland-Morris disability score.
2. To evaluate associations between receiving early imaging and the following disability measures one year after injury: receiving wage replacement benefits, self-report of not working due to injury, and rate of ending work disability.

Chapter 2. Factors associated with early MRI utilization for acute occupational low back pain

I. CHAPTER SUMMARY

Background: Early imaging may be associated with increased use of services for treatment and costs. In order to understand utilization and most appropriately apply guidelines, it is important to identify factors associated with early imaging use for occupational LBP.

Objective: To identify demographic, job-related, psychosocial, and clinical factors associated with use of MRI within 6 weeks from injury (early MRI) among workers' compensation claimants with acute occupational LBP.

Methods: Workers (N=1830) were interviewed 3 weeks (median) after submitting a workers' compensation claim for a back injury. Demographic, work, health, clinical, and injury characteristics were ascertained from interviews, medical records, and administrative data. Modified Poisson regression analyses identified factors associated with early imaging use.

Results: Among respondents, 362 (19.8%) received an early MRI. Multivariable regression showed that workers with elevated work fear-avoidance, higher Roland scores, or increased injury severity were more likely to receive early imaging than counterparts with lower levels or scores. Initial visit type with a surgeon was associated with 78% greater likelihood of receiving an early MRI, compared to primary care physician (IRR 1.78, 95% CI: 1.08-2.92). Having a chiropractor as the initial provider was associated with a reduced likelihood of early MRI (IRR 0.53, 95% CI: 0.42-0.66). Male workers were

43% more likely to receive MRI within 6 weeks of injury than females (IRR 1.43, 95% CI: 1.12-1.82).

Conclusions: Nearly 20% of injured workers with LBP receive early MRI, a rate similar to that reported elsewhere. Receiving an MRI within the first 6 weeks of injury may lead to greater subsequent interventions, potentially poorer outcomes, and increased healthcare expenditures. Based on the characteristics of patients with uncomplicated occupational LBP, providers may be able to provide tailored care, and providers and policy-makers may better understand the utilization of imaging and adherence to clinical guidelines.

II. INTRODUCTION

Approximately one-quarter of working adults are affected by low back pain (LBP) during their career and 10-20% with a work-related low back injury do not return to work.(3, 4, 68) Occupational LBP accounts for approximately 30% of workers' compensation claims, and these claims constitute a disproportionately higher percentage of total workers' compensation costs.(69, 70)

Clinical practice guidelines for acute LBP recommend a conservative approach for non-traumatic cases avoiding routine spinal imaging within the first 4-6 weeks of symptoms (during the acute phase of LBP).(2, 44, 52, 53, 71) Exceptions include patients with the following "red flags": age under 20, infection, history of cancer, IV drug use, prolonged use of corticosteroids, osteoporosis, older age (over 50 or 70, depending on the guideline), or focal neurologic deficit with progressive or disabling symptoms.(8, 44)

Although magnetic resonance imaging (MRI) for LBP within the first six weeks of symptoms is not recommended except in cases with red flags, approximately 20% receive

MRI within first 4-6 weeks.(61) Early MRI may be associated with increased use of services for treatment and costs(56, 58) and little additional benefit of diagnostic insight or improved health outcomes.(33) Imaging itself may have deleterious effects on patient well-being.(33, 72) To our knowledge, no study has yet evaluated the factors associated with early MRI for occupational LBP.

Our objective was to identify demographic, job-related, psychosocial, and clinical factors associated with use of early MRI among a population-based cohort of workers' compensation claimants with acute LBP.

III. MATERIAL AND METHODS

A. Data sources

Data were obtained from the Washington Workers' Compensation Disability Risk Identification Study Cohort (D-RISC), a population-based study designed to identify risk factors for chronic disability among workers with acute back injury (details reported elsewhere).(65-67) D-RISC combined administrative claims and medical billing data provided by the Washington State Department of Labor and Industries (L&I), which operates a workers' compensation program that provides no-fault industrial insurance insurance covering two-thirds of all non-federal Washington workers (the remaining 1/3 are workers employed by large, self-insured companies, for whom data is not available).

D-RISC study participants were limited to workers over 18 years old with a back sprain/strain, an accepted workers' compensation claim, who received compensation for missing at least 4 days from work, and were not hospitalized in the acute period after injury.(73)

Trained personnel conducted computer-assisted telephone interviews with participants approximately 3 weeks (median 18 days, range 10-58 days) after filing the claim with L&I. Interviews included questions regarding overall and injury-specific health, personal, and work characteristics. The University of Washington Institutional Review Board approved the study, and participants provided informed consent and were paid $10.

B. Variable Definitions

Variables were selected *a priori*, informed by health services utilization models and current literature.(63, 74) The primary outcome variable for all analyses was receipt of early MRI (yes/no), defined as receiving a lumbar MRI within 6 weeks ($\leq$ 42 days) after injury date. Dates of procedures from the workers' compensation medical bill payment database were used to calculate the duration between injury and MRI.

Interviews were completed approximately one month after injury (median 30 days, range 14-90 days). To account for the time lag between injury and interview, a lag variable (number of days after injury) was calculated for each worker.

Demographics. Participants provided demographic information that included race, ethnicity, education, income, and marital status.

Health status. Workers provided self-reported health status (aside from injury) for the year before injury and concurrent with the interview (current), categorized on a Likert scale. Body mass index (BMI) was categorized as normal (<25), overweight (25-29), obese (30-34), and very obese (>34). Catastrophizing, a psychosocial health measure of coping response, was categorized into three levels: low (<1), moderate (1-2.9), high (3-

4).(75) Work fear-avoidance was assessed by averaging responses to 2 items from the Fear-Avoidance Beliefs Questionnaire and categorized as very low (<3), low-moderate (3.1-4.9), high (5-5.9) and very high (6).(76) Mental health status was measured using the SF-36 (version 2) and scored based on U.S. population norms: 2 or more standard deviations (SD) below the general population mean (<30), 1-2 SD below (30-39.9), 1 SD below (40-49.9), and at/above the mean (≥50).(77, 78)

Employment. L&I administrative claims data were used to determine whether the worker had a previous compensable back claim. Workers reported overall job satisfaction and whether their employer offered accommodations for the injury (e.g., change in physical environment, tasks, work-schedule, job positions, or part-time work). Employment industry was determined according to the North American Industry Classification System.(79) Physical demands were self-reported as sedentary/light, medium, heavy, or very heavy, based on the amount of lifting, carrying, pushing, or pulling loads associated with typical work activities.(66)

Type of first medical visit. The type of first office visit was obtained from the workers' compensation medical bill payment database. This variable was categorized as primary care physician, occupational health physician, chiropractor, surgeon, emergency department, or other provider (including specialists and physical medicine).

Injury characteristics. Measures describing the worker's back injury included both self-report and clinical characteristics. Pain intensity refers to any pain in the last week, either from injury or other causes, on a 0-10 scale, categorized as no/low pain (0-3), moderate (4-6), and high (7-10).(80) The Roland-Morris disability questionnaire assesses disability due to LBP and was categorized in 4 groups based on scores 0 to 24: 0-6, 7-13, 14-18, and 19-24 (higher scores reflecting higher levels of disability).(81, 82) Medical record review by occupational health nurses provided a clinical estimate of injury category, defined as moderate sprain/strain, major sprain/strain, or substantial immobility/radiculopathy.(83)

C. Statistical Analysis

Workers whose medical claim reported lumbar MRI $\leq$ 42 days after injury date were considered to have received an early MRI. This cutoff value reflects clinical guidelines, which recommend waiting at least 6 weeks before imaging.(2, 44, 52, 53, 71) Rates of radiography and CT were calculated for comparison. Descriptive and inferential analyses were performed using STATA/IC 10.1 for Macintosh (Stata Corp., College Station, TX).

Univariate analyses of demographic, health status, employment, provider, and injury variables were conducted using Pearson χ^2 tests. Bivariate relationships evaluated the association between each variable and early MRI. Because the prevalence of the outcome was greater than 10%, a modified Poisson approach with robust error variance was used.(84) Multivariable models estimated the likelihood of receiving MRI within 6 weeks of injury for each factor while controlling for covariates (including a lag variable for time between injury and interview). The results of analyses were presented as incident rate ratios (IRRs) with 95% confidence intervals; IRR is the inverse of natural logarithm of β (or e^{β}) and demonstrates the multiplicative influence of one unit change in exposure on the rate of the outcome.

Chi-square (χ^2) analyses were used to assess multicollinearity by testing associations between pairs of related categorical variables. For pairs that were strongly associated ($p<0.05$), each was removed sequentially from the full model to evaluate the effect on coefficients.

Seventeen percent of all study subjects (N=322) received MRI prior to completing the D-RISC questionnaire, which could have influenced responses to interview questions. To address this issue, a separate model (Table 2.2, Model 2) excluded interview questions that may exhibit bias (e.g., health status, mental health measures, pain intensity).

To evaluate whether receiving early MRI may be attributed to planning of subsequent spinal injection procedures, we calculated the proportion of workers who received a spinal injection in 30 days after the early MRI. Injections included caudal, facet lumbar/sacral, transforaminal lumbar/sacral, or sacroiliac joint injections.

IV. RESULTS

From July 2002 to April 2004, 4354 workers were identified, of whom 49% agreed to participate in the D-RISC study, 27% could not be contacted, 3% were ineligible due to language limitations, and 21% declined to participate. Of the 2147 subjects who agreed to participate, 240 were excluded for lacking work disability compensation, and 22 others were excluded for other reasons. The final D-RISC sample of 1885 workers, compared with non-participants (N=1776), was slightly older (age mean (SD) 39.4 (11.2) vs. 38.2 (11.1) years, $p<0.001$) and included more women (32% vs. 26%, $p<0.001$).(66) The majority of workers filed a claim within 2 months after injury (97%). Among those who did not (N=55), claims were filed up to 9 months after injury and interviews were conducted up to a year after injury For this study, these workers were excluded, the final study sample consisted of 1830 workers

The median time from injury to the first medical appointment was 2 days (mean=5, SD=7) Among the 1830 workers, 362 (19 8%) received an MRI within 42 days of the injury (early MRI) (Table 2 1) Of all workers, 34 4% (N=630) received an MRI at any time in 1 year after injury Overall, the mean time to MRI was 60 days (SD=67) Among those who received an early MRI, the mean time to MRI was substantially less 21 days (SD=11, p<0 001) Compared to MRI, more workers (N=1002, 54 8%) received at least one lumbar radiograph in the year following injury (884 underwent radiography within the first 6 weeks of injury) Far fewer workers received a lumbar CT in 1 year (N=64, 3 5%), 27 received CT within the first 6 weeks of injury

Table 2.1: Demographic, work, clinical, and health history characteristics of D-RISC workers who received early MRI and those who did not.

	MRI within 6 weeks (N=362) N (%)	Consistent with guidelines (N=1468) N (%)	P-value
DEMOGRAPHICS			
Age (at injury)			0 005
Under 24 yrs	24 (6 6)	169 (11 5)	
25-34 yrs	79 (21 8)	387 (26 4)	
35 44 yrs	124 (34 3)	430 (29 3)	
45-54 yrs	101 (27 9)	331 (22 5)	
Over 55 yrs	34 (9 4)	151 (10 3)	
Sex			0 031
Female	99 (27 3)	488 (33 2)	
Male	263 (72 7)	980 (66 8)	
Race			0 013
White	284 (78 5)	1040 (70 8)	
Non-white	76 (21 0)	412 (28 1)	
Ethnicity			0 367
Non-Hispanic	306 (84 5)	1202 (81 9)	
Hispanic	54 (14 9)	249 (17 0)	
Education			0 576
Less than high school	45 (12 4)	195 (13 3)	
High school diploma/GED	133 (36 7)	491 (33 4)	

	MRI within 6 weeks (N=362) N (%)	Consistent with guidelines (N=1468) N (%)	P-value
Some college	159 (43.9)	648 (44.1)	
College degree	25 (6.9)	133 (9.1)	
Household income ($)			0.031
< 30,000	123 (34.0)	605 (41.2)	
30-45,000	96 (26.5)	362 (24.7)	
45-70,000	94 (26.0)	315 (21.5)	
>70,000	41 (11.3)	131 (8.9)	
Marital status			0.113
Married	192 (53.0)	742 (50.5)	
Living with partner	52 (14.4)	205 (14.0)	
Divorced	78 (21.5)	278 (18.9)	
Other	40 (11.0)	240 (16.3)	
HEALTH CHARACTERISTICS			
Body Mass Index (BMI)			0.190
Normal <25	96 (26.5)	453 (30.9)	
Overweight 25-29	142 (39.2)	560 (38.1)	
Obese 30-34	80 (22.1)	293 (20.0)	
Very obese >34	39 (10.8)	124 (8.4)	
Health in year before injury			0.730
Excellent	90 (24.9)	330 (22.5)	
Very good	125 (34.5)	537 (36.6)	
Good	107 (29.6)	447 (30.4)	
Fair/Poor	40 (11.0)	151 (10.3)	
SF-36 Mental health score[a]			0.000
2 SD below population mean	84 (23.2)	184 (12.5)	
1-2 SD below population mean	105 (29.0)	289 (19.7)	
1 SD below population mean	101 (27.9)	361 (24.6)	
At or above population mean	72 (19.9)	632 (43.1)	
Catastrophizing[b] **(0-4)**			0.000
Low (<1)	43 (11.9)	379 (25.8)	
Moderate (1-2.9)	188 (51.9)	793 (54.0)	
High (3-4)	131 (36.2)	296 (20.2)	
Work fear-avoidance[c] **(0-6)**			0.000
Low (0-2.9)	34 (9.4)	332 (22.6)	
Moderate (3-4.9)	91 (25.1)	497 (33.9)	
High (5-5.9)	143 (39.5)	405 (27.6)	
Very high (6)	94 (26.0)	234 (15.9)	
CLINICAL CHARACTERISTICS			
Type of first medical visit			0.000
Primary care	177 (48.9)	635 (43.3)	
Occupational medicine	18 (5.0)	41 (2.8)	
Chiropractor	71 (19.6)	488 (33.2)	
Surgeon	13 (3.6)	26 (1.8)	
Emergency room/clinic	75 (20.7)	254 (17.3)	
Other	8 (2.2)	24 (1.6)	
WORK CHARACTERISTICS			

	MRI within 6 weeks (N=362) N (%)	Consistent with guidelines (N=1468) N (%)	P-value
Offered job accommodation for disability			0.000
Yes	131 (36.2)	704 (48.0)	
No	224 (61.9)	748 (51.0)	
1+ previous compensable back claims			0.008
Yes	89 (24.6)	268 (18.3)	
No	273 (75.4)	1190 (81.1)	
Job satisfaction			0.563
Not at all	16 (4.4)	87 (5.9)	
Not too satisfied	30 (8.3)	131 (8.9)	
Somewhat satisfied	160 (44.2)	604 (41.1)	
Very satisfied	156 (43.1)	642 (43.7)	
Industry			0.043
Natural resources	10 (2.8)	80 (5.4)	
Construction	72 (19.9)	253 (17.2)	
Manufacturing	40 (11.0)	108 (7.4)	
Trade/transportation	80 (22.1)	366 (24.9)	
Management	65 (18.0)	232 (15.8)	
Education/health	51 (14.1)	230 (15.7)	
Hospitality	44 (12.2)	199 (13.6)	
Physical demands at work			0.010
Light	58 (16.0)	308 (21.0)	
Medium	112 (30.9)	470 (32.0)	
Heavy	80 (22.1)	354 (24.1)	
Very heavy	108 (29.8)	330 (22.5)	
INJURY CHARACTERISTICS			
Health status at time of interview			0.300
Excellent	70 (19.3)	290 (19.8)	
Very good	123 (34.0)	531 (36.2)	
Good	121 (33.4)	466 (31.7)	
Fair/poor	46 (12.7)	180 (12.3)	
Pain intensity the last week[d]			0.000
Low/no pain (0-3)	38 (10.5)	409 (27.9)	
Moderate (4-6)	105 (29.0)	381 (26.0)	
High (7-10)	219 (60.5)	675 (46.0)	
Roland-Morris disability questionnaire score[e]			0.000
Equal to or less than 6	13 (3.6)	412 (28.1)	
7-12	48 (13.3)	336 (22.9)	
13-18	120 (33.1)	408 (27.8)	
Equal to or over 18	181 (50.0)	312 (21.3)	
Medical record documented injury category			0.000
Mild sprain/strain	98 (27.1)	906 (61.7)	
Major sprain/strain	69 (19.1)	308 (21.0)	
Radiculopathy or reflexes absent	193 (53.3)	246 (16.8)	

Frequency counts do not always sum to total because of missing responses or rounding.
Values are N (%) and p-values indicate χ^2 tests.
[a] SF-36 MH, Short Form-36 version 2 Mental Health scale.[24,25]
[b] Mean of responses to 3 questions from the Pain Catastrophizing scale.[22]

	MRI within 6 weeks (N=362) N (%)	Consistent with guidelines (N=1468) N (%)	P-value

[c] Mean of responses to two questions from the Fear-Avoidance Beliefs Questionnaire work scale [23]
[d] Any pain in the last week, scale ranges from 0-10 [27]
[e] Roland-Morris disability questionnaire measures physical functioning relating to back pain [28 29]

The following variables were not associated with early MRI bivariately or in multivariate analyses: marital status, BMI, past or current health status, and job satisfaction. Age, race, education, catastrophizing, job accommodations, previous compensable back claims, and self-reported pain intensity were associated with early MRI in bivariate analyses (Table 2.1) but were not significant in multivariate model after adjusting other covariates (Table 2.2).

Multivariable regression showed that male workers were 43% more likely to receive an early MRI than females (IRR 1.43, 95% CI: 1.12-1.82) and workers whose initial visit type was with a surgeon were 78% more likely to receive an early MRI than those who saw a primary care physician initially (IRR 1.78, 95% CI: 1.08-2.92) (Model 1, Table 2). Workers with a chiropractor as the initial provider were half as likely to receive an early MRI, compared to workers with the same demographic and injury characteristics whose initial provider was a primary care physician (IRR 0.53, 95% CI: 0.42-0.66). Compared to workers with Roland scores below 6, workers with scores over 18 were nearly 6 times more likely to receive an early MRI, holding all other covariates constant (IRR 5.87, 95% CI: 3.16-10.89). Similarly, controlling for all other factors, the risk of early MRI was three times higher for workers with radiculopathy compared to workers with mild sprains (IRR 3.04, 95% CI: 2.44-3.79).

Regarding potential red flags and characteristics that may justify an early MRI, 51 workers (2.8%) were under the age of 20, 373 (20.4%) were over 50, and 6 were over 70 years old. Among workers who received an early MRI, 39.8% (N=144) received at least one injection in the year following injury. The mean time between MRI and injection was 105 days (SD=84 days) with 13.5% (N=49) receiving an injection within 30 days of the early MRI.

Table 2.2: Factors associated with the likelihood of a worker receiving MRI within 6 weeks of injury for low back sprain/strain.

	Unadjusted		Model 1		Model 2	
	IRR	95% CI	IRR	95% CI	IRR	95% CI
DEMOGRAPHICS						
Age (at injury)						
Under 24 yrs	0.56	0.37-0.83	0.84	0.57-1.24	0.81	0.55-1.19
25-34 yrs	0.76	0.59-0.98	0.93	0.73-1.18	0.91	0.71-1.15
35-44 yrs	1.00	Ref.	1.00	Ref.	1.00	Ref.
45-54 yrs	1.04	0.83-1.32	0.95	0.77-1.17	0.97	0.78-1.21
Over 55 yrs	0.82	0.58-1.15	1.00	0.72-1.39	0.85	0.61-1.18
Sex						
Female	1.00	Ref.	1.00	Ref.	1.00	Ref.
Male	1.25	1.02-1.00	1.43	1.12-1.82	1.24	0.98-1.58
Race						
White	1.00	Ref.	1.00	Ref.	1.00	Ref.
Non-white	0.73	0.58-0.91	0.78	0.61-1.00	0.83	0.64-1.07
Ethnicity						
Non-Hispanic	1.00	Ref.	1.00	Ref.	1.00	Ref.
Hispanic	0.88	0.68-1.14	1.33	1.00-1.76	1.37	1.02-1.83
Education						
Less than high school	0.88	0.65-1.19	0.86	0.64-1.15	0.90	0.67-1.22
High school diploma/GED	1.00	Ref.	1.00	Ref.	1.00	Ref.
Some college	0.92	0.75-1.14	0.84	0.70-1.02	0.83	0.68-1.00
College degree	0.74	0.50-1.10	0.79	0.54-1.16	0.77	0.53-1.13
Household income ($)						
< 30,000	1.00	Ref.	1.00	Ref.	1.00	Ref.
30-45,000	1.24	0.98-1.58	1.07	0.85-1.35	1.09	0.85-1.38
45-70,000	1.36	1.07-1.73	1.11	0.85-1.43	1.10	0.85-1.43
>70,000	1.41	1.03-1.93	1.39	1.01-1.90	1.25	0.90-1.74
Marital status						
Married	1.00	Ref.	1.00	Ref.	1.00	Ref.
Living with partner	0.98	0.75-1.29	1.09	0.84-1.42	1.04	0.80-1.36
Divorced	1.07	0.84-1.35	1.04	0.83-1.29	1.10	0.88-1.39

	Unadjusted		Model 1		Model 2	
	IRR	95% CI	IRR	95% CI	IRR	95% CI
Other	0.69	0.51-0.95	0.84	0.63-1.14	0.76	0.56-1.02
HEALTH CHARACTERISTICS						
Body Mass Index (BMI)						
Normal <25	1.00	Ref.	1.00	Ref.	1.00	Ref.
Overweight 25-29	1.16	0.92-1.46	1.06	0.86-1.32	1.09	0.87-1.35
Obese 30-34	1.23	0.94-1.60	1.10	0.85-1.41	1.17	0.91-1.50
Very obese >34	1.37	0.99-1.90	1.07	0.79-1.46	1.19	0.87-1.63
Health in year before injury						
Excellent	1.00	Ref.	1.00	Ref.		
Very good	0.88	0.69-1.12	0.80	0.61-1.05		
Good	0.90	0.70-1.16	0.88	0.67-1.17		
Fair/Poor	0.98	0.70-1.36	0.88	0.62-1.24		
SF-36 Mental health score						
2 SD below population mean	3.06	2.31-4.06	1.34	1.00-1.81		
1-2 SD below population mean	2.61	1.98-3.43	1.24	0.94-1.64		
1 SD below population mean	2.14	1.62-2.82	1.38	1.06-1.81		
At or above population mean	1.00	Ref.	1.00	Ref.		
Catastrophizing						
Low (<1)	1.00	Ref.	1.00	Ref.		
Moderate (1-2.9)	1.88	1.38-2.57	1.00	0.73-1.36		
High (3-4)	3.01	2.19-4.13	1.15	0.82-1.61		
Fear avoidance						
Low (0-2.9)	1.00	Ref.	1.00	Ref.		
Moderate (3-4.9)	1.67	1.15-2.42	1.32	0.94-1.85		
High (5-5.9)	2.81	1.98-3.99	1.73	1.24-2.41		
Very high (>6)	3.09	2.15-4.43	1.54	1.07-2.22		
CLINICAL CHARACTERISTICS						
Type of first medical visit						
Primary care	1.00	Ref.	1.00	Ref.	1.00	Ref.
Occupational medicine	1.40	0.93-2.10	1.28	0.90-1.82	1.21	0.84-1.74
Chiropractor	0.58	0.45-0.75	0.53	0.42-0.66	0.52	0.41-0.65
Surgeon	1.53	0.96-2.43	1.78	1.08-2.92	1.51	0.95-2.42
Emergency room	1.05	0.82-1.33	0.90	0.72-1.13	0.98	0.78-1.22
Other	1.15	0.62-2.12	1.17	0.66-2.09	1.24	0.67-2.32
WORK CHARACTERISTICS						
Offered job accommodation						
Yes	1.00	Ref.	1.00	Ref.	1.00	Ref.
No	1.47	1.21-1.78	1.13	0.94-1.35	1.40	1.17-1.68
1+ previous compensable back claims						
Yes	1.34	1.08-1.65	1.12	0.91-1.36	1.15	0.94-1.42
No	1.00	Ref.	1.00	Ref.	1.00	Ref.
Job satisfaction						
Not at all	0.79	0.50-1.27	0.66	0.43-1.00		
Not too satisfied	0.95	0.67-1.36	0.84	0.60-1.17		
Somewhat satisfied	1.07	0.88-1.30	1.09	0.91-1.30		
Very satisfied	1.00	Ref.	1.00	Ref.		
Industry						

	Unadjusted		Model 1		Model 2	
	IRR	95% CI	IRR	95% CI	IRR	95% CI
Natural resources	0.62	0.33-1.15	0.70	0.40-1.24	0.65	0.37-1.15
Construction	1.24	0.93-1.64	1.13	0.86-1.48	1.26	0.96-1.64
Manufacturing	1.51	1.08-2.10	1.39	1.02-1.89	1.39	1.01-1.90
Trade/transportation	1.00	Ref.	1.00	Ref.	1.00	Ref.
Management	1.22	0.91-1.63	1.26	0.97-1.64	1.22	0.93-1.60
Education/health	1.01	0.74-1.39	1.15	0.83-1.58	1.16	0.83-1.61
Hospitality	1.01	0.72-1.41	1.11	0.83-1.47	1.15	0.85-1.56
Physical demands at work						
Light	1.00	Ref.	1.00	Ref.	1.00	Ref.
Medium	1.21	0.91-1.62	1.14	0.88-1.48	1.17	0.90-1.53
Heavy	1.16	0.85-1.58	1.02	0.76-1.37	1.17	0.87-1.57
Very heavy	1.56	1.17-2.07	1.23	0.93-1.62	1.44	1.09-1.91
INJURY CHARACTERISTICS						
Health status at time of interview						
Excellent	1.00	Ref.	1.00	Ref.		
Very good	0.97	0.74-1.26	1.06	0.79-1.41		
Good	1.06	0.81-1.38	0.98	0.73-1.31		
Fair/poor	1.05	0.75-1.46	1.01	0.70-1.44		
Pain intensity the last week						
Low/no pain (1-3)	1.00	Ref.	1.00	Ref.		
Mild (4-6)	2.54	1.79-3.60	0.86	0.62-1.20		
Moderate/major pain (7-9)	2.88	2.08-3.99	0.92	0.67-1.26		
Roland-Morris disability questionnaire score						
Equal to or less than 6	1.00	Ref.	1.00	Ref.		
7-12	4.09	2.25-7.43	2.98	1.63-5.46		
13-18	7.43	4.25-12.98	4.63	2.54-8.42		
Equal to or over 18	12.00	6.94-20.76	5.87	3.16-10.89		
Medical record documented injury category						
Mild sprain/strain	1.00	Ref.	1.00	Ref.	1.00	Ref.
Major sprain/strain	1.88	1.41-2.49	1.49	1.13-1.95	1.87	1.42-2.47
Radiculopathy or reflexes absent	4.50	3.63-5.59	3.04	2.44-3.79	4.55	3.67-5.64

All covariates listed are included in the Model 1. Model 2 does not adjust for health in year before injury, SF-36 mental health score, catastrophizing, fear avoidance, job satisfaction, health status at the time of the interview, pain intensity, or Roland-Morris disability questionnaire score.

Analyses for multicollinearity showed that the following pairs of variables were strongly associated ($p<0.05$): pain intensity/Roland, injury severity/Roland, pain intensity/injury severity, past/current health status, catastrophizing/SF-36 mental health, fear-avoidance/catastrophizing, catastrophizing/SF-36 mental health, and Roland with each of the mental health measures (catastrophizing, fear-avoidance, and SF-36 mental health). Removal of each variable from the full model did not materially change the model associations or conclusions.

The multivariable model was run with and without the lag variable representing time between injury and interview; the model associations and conclusions did not change upon exclusion of the lag variable. Model 2 (Table 2.2) excluded variables that could be biased due to the timing of the interview. Risk estimates exhibit patterns similar to Model 1; magnitudes of the associations did not differ substantially.

V. DISCUSSION

This research identifies factors associated with receiving an early lumbar MRI among workers with non-specific, acute uncomplicated LBP. Multivariable results indicate that male sex, type of first medical visit, functional status, medically documented injury severity, and fear-avoidance are strongly associated with receiving early MRI for occupational LBP.

Although injury severity is associated with an increased likelihood of receiving advanced imaging for LBP (85), guidelines discourage early imaging unless patients have signs, symptoms, or characteristics suggestive of an underlying “red flag” condition, such as infection, tumor, or serious neurological impairment.(52, 53) We found that workers with radiculopathy or more severe neurological impairments were more likely to receive early imaging. It is possible that a small minority of early MRI recipients in this group may have borne definite red flag elements that justify early imaging, however, only 21.2% of the cohort were either younger than 20 or older than 50, and individuals in these age groups were not disproportionately at risk for early MRI (results not shown). While data on history of cancer, infection, intravenous drug use or HIV were not available, the prevalence of these conditions is likely to be very low in a relatively young working population. Among workers who received an early MRI, fewer than 15% underwent an injection procedure within 30 days of receiving the MRI, suggesting that many early MRIs may not have been used for injection planning purposes.

Studies have shown that neurosurgeon, neurologist (86) and orthopedic surgeon (85, 87) providers are associated with increased likelihood of receiving advanced imaging (though not necessarily early). Although we were unable to assess each provider type individually due to sample sizes, our research shows that workers with an initial office visit with a surgeon provider (general, neurological, or orthopedic surgery) were highly likely to receive early MRI, independent of injury severity, suggesting that initial visit type also plays an important role in the utilization of early imaging. Early imaging should be considered a supplemental diagnostic tool for patients with red flags after the completion of a detailed medical history and physical exam.(2, 30) Some providers, especially those who typically see patients with severe injuries, such as surgeon providers, may routinely image most or all patients.(85, 87) This may result in patients with less severe injuries, or without red flags, receiving early MRI and these providers having higher likelihood of early MRI than others.

Chiropractic initial visits were associated with a nearly 50% lower likelihood of MRI within the first 6 weeks of LBP symptoms. Chiropractic providers are actually more likely to use radiographs(85), however, this utilization may be less costly to L&I, as the cost of radiographs is substantially less than MRIs (L&I 2009 reimbursement rates $85 vs. $1,131) and clinical outcomes do not differ by imaging modality.(56) Research suggests initial chiropractic care results in significantly lower costs (88) and greater patient satisfaction (89)

Fear-avoidance beliefs are an important psychosocial factor in the recovery of acute LBP, causing patients to avoid activities that are anticipated to cause or exacerbate pain (e g work) (76, 90) Research shows that holding elevated fear-avoidance beliefs is associated with increased healthcare use (91) Our finding that workers with higher fear-avoidance beliefs were more likely to receive an early MRI than workers with low fear-avoidance beliefs is consistent with the literature The use of early imaging may be particularly concerning for patients with elevated fear-avoidance beliefs, as they may be more predisposed to feel threatened by diagnostic labels (92), develop chronic LBP (93, 94), be prescribed narcotics (91), or remain on disability (90, 95)

The population-based design, large sample size, and the availability of detailed independent variables contribute to the strength and unique nature of this research This study has several limitations First, this cohort includes cases with ≥ 4 days of compensated lost work time, so results may not be generalizable to workers with less severe or non-compensable injuries Second, 17% of workers received imaging before the interview was conducted (N=322), potentially introducing bias to the study However, eliminating potentially biased covariates did not substantially change the study results Third, information regarding a workers' history of cancer, intravenous drug use, and HIV-status were not available for this analysis, for these red flags, early MRI would have been appropriate Finally, the purpose, scope, and design of this study limited its ability to assess several factors that warrant future research This study did not incorporate information from providers regarding the reason for ordering an MRI It was also not possible to ascertain the appropriateness of the imaging received, or whether the imaging was truly necessary for a particular patient. Lastly, early imaging may influence outcomes, such as utilization, costs, health, or disability, but that analysis was beyond the scope of this study. These are important aspects in evaluating the potential overutilization of imaging and should be addressed by suitably designed, future research.

VI. CONCLUSION

To our knowledge, this is the first study to evaluate individual-level factors, including self-reported pain and functioning, associated with early MRI for acute LBP. Results show that early MRI for LBP is a common practice, which may contribute to increased resource utilization and costs.(56, 96) It is prudent for providers to be aware of clinical practice guidelines and follow recommendations to limit advanced imaging in the first 4-6 weeks of LBP symptoms. Given the results of this study, providers could provide more customized care, based on the characteristics of patients with uncomplicated occupational LBP and policy-makers may seek to direct patients to certain types of providers early in the course of their LBP.

Chapter 3. Utilization and costs associated with early magnetic resonance imaging for acute occupational low back pain

I. CHAPTER SUMMARY

Background. Evidence-based guidelines recommend advanced imaging only after the first 6 weeks of symptoms for uncomplicated, non-specific LBP. Early imaging may be associated with increased healthcare utilization and costs.

Objectives. To evaluate utilization and costs associated with use of early MRI (within the first 6 weeks of injury) among workers with LBP.

Methods. A prospective, population-based cohort study was conducted using administrative claims and interview data from Washington State workers' compensation claimants with acute, non-specific LBP. Modified Poisson regression was used to assess the impact of early MRI on the likelihood of imaging, injections, surgery, chiropractor, PT/OT, and outpatient visits in the year after injury. Two-part models were used to compute adjusted outpatient, inpatient, pharmacy, and workers' compensation costs and number of office visits associated with early MRI.

Results. Of 1,770 workers, 331 (18.7%) received early MRI. In the year after injury, workers with early imaging were 41.7% less likely to receive a subsequent MRI (95% CI: 25.5-54.4) and 44.0% more likely to have an outpatient visit (95% CI: 32.5-56.6), after adjusting for covariates. Compared to imaging consistent with guidelines, early imaging was associated with significantly more outpatient and PT/OT visits and higher adjusted mean costs for outpatient and inpatient care, disability compensation, and other workers' compensation expenses.

Conclusions. Early advanced imaging for LBP results in greater likelihood of utilization for some healthcare services as well as increased costs. Adherence to guidelines is crucial to prevent unnecessary care and the potential for adverse outcomes.

II. INTRODUCTION

Clinical practice guidelines for acute low back pain (LBP) maintain that routine spinal imaging tests are not necessary for patients who do not present with complications, or "red flags," within 4-6 weeks of symptom onset.(2, 42, 44, 52) Red flags include age under 20 or over 70 (or 50, depending on the guideline), suspicion or evidence of infection, history of cancer, IV drug use, prolonged use of corticosteroids, osteoporosis, or focal neurologic deficit with progressive or disabling symptoms.(44) Recent research suggests that approximately 20% of all LBP cases receive early magnetic resonance imaging (MRI) (within the first 4-6 weeks of symptoms), a proportion of whom may be receiving unnecessary care.(61) The propensity to adopt and utilize newly emerging technologies for advanced imaging, combined with a general lack of utilization controls, generates a concerning situation from the perspective of payers, especially public payers facing increasing budgetary constraints. Use of costly procedures, such as MRI for LBP may be associated with increased treatment and costs, without concomitant improvements in health outcomes.(56, 58) With early imaging potentially catalyzing earlier, more intensive treatment for LBP, a patient with early imaging may utilize more healthcare and cost more than an his/her equivalent who waited 4-6 weeks before receiving MRI.(59)

In Washington State, the State Fund provides workers' compensation insurance coverage for more than 2.5 million workers. Back injuries constitute 18% of all claims and 23% of all workers' compensation costs (fiscal year 2010).(20) In 2008, charges to the State Fund for lumbar MRI exceeded $7.4 million.(97) In response to rapidly increasing costs, in 2009 the Washington legislature mandated that State health care agencies consider methods to implement best practice guidelines for the use of advanced imaging.(62)

Given high costs facing the workers' compensation State Fund and the potential for workers to have unique needs compared to other patients, it is important to evaluate how use of early MRI for acute occupational LBP may contribute to healthcare utilization and costs. In a recent study of national workers' compensation claimant records, Webster and colleagues examined outcomes associated with workers who underwent early MRI. Results showed that 22% of LBP patients received early MRI, and authors concluded that there was limited indication of necessity for early imaging in most cases, suggesting overutilization of this technology.(61) Authors also found that early MRI was associated with higher total medical costs (post-MRI) and longer duration of disability.

This study uses claims and interview data to evaluate the healthcare utilization and costs associated with early imaging among Washington State workers' compensation claimants with acute, non-specific LBP.

III. METHODS

This population-based cohort study evaluates the association between early MRI and healthcare utilization and costs incurred within 1 year following an acute occupational low back sprain or strain among workers' compensation claimants in Washington State.

A. Data source and study population

Data were obtained from the Washington Workers' Compensation Disability Risk Identification Study Cohort (D-RISC), a population-based cohort study designed to identify risk factors for chronic disability among workers with acute back injury (details reported elsewhere).(66) Data included administrative and medical claims data provided by the State Department of Labor and Industries (L&I), which operates the state workers' compensation program (the State Fund). The State Fund covers two-thirds of all non-federal Washington workers (the remaining third are employed by large, self-insured companies, for whom complete data is unavailable).

The following inclusion criteria applied to D-RISC study participants: 18 years and older, back sprain or strain, accepted claim with the State Fund, received compensation for missing at least 4 days of work, not hospitalized for their injury.(66) Administrative and medical data associated with the back injury claim were collected for all participants. Medical claims data provided types, dates, providers, and allowed charges for all procedures associated with the back injury. Administrative data provided data on total compensation for time away from work due to the injury.

D-RISC participants completed a telephone interview administered by trained personnel approximately 3 weeks (median 18 days, range 10-58 days) after the injury claim was filed with the State Fund and one year later (median 343 days, range 332-497 days). Interview questions ascertained overall and injury-specific health, personal and work characteristics. Medical record review by occupational health nurses ascertained a clinical estimation of injury severity.(83) The University of Washington Institutional

Review Board approved the study, and participants provided informed consent and were compensated $10 at baseline and follow-up.

B. Measures

The independent variable of interest was receipt of early MRI (yes/no), defined as receiving a lumbar MRI within 6 weeks of the reported date of injury. This cutoff value reflects guidelines.(2, 52) Duration between injury and MRI was calculated as the difference between injury date and a worker's first MRI date, identified in the State Fund's medical bill payment database. Workers who received an early MRI were compared to those whose care was consistent with guidelines (did not receive an early MRI or received an MRI after the first 6 weeks of symptoms).

Allowed medical bills were used to identify utilization and costs of healthcare resources. Utilization and costs were calculated for the year following injury, excluding the first 6 weeks of symptoms and health care utilization. This cutoff value ensured that workers were compared based on their utilization and costs subsequent to being eligible to receive an early MRI.

C. Utilization

Procedures were defined using Current Procedural Terminology (CPT-4) codes, Healthcare Common Procedure Coding System (HCPCS) codes, or codes specific to L&I; provider types and specialties were used to determine type of service rendered, when necessary. (Definitions of measures are included in the appendix.) Utilization measures for distinct services were limited to lumbar and lumbosacral procedures, because non-lumbar procedures may be the result of different disease processes, and this research focused specifically on LBP. Utilization measures were calculated as the total number of daily procedures/visits with a maximum of one visit per day.

Analyses included utilization of the following services for each worker: lumbar imaging (CT, MRI, radiography), lumbosacral injections, lumbar surgery, prescription medication, chiropractor visits and therapy, physical or occupational therapy (PT/OT), and outpatient visits.

D. Costs

Five cost categories were assessed in this analysis: outpatient services, prescription drugs, inpatient services, other workers' compensation costs, and disability compensation. Outpatient, prescription, and inpatient, and other workers' compensation costs were defined as the total reimbursed (allowed) amount delivered to facilities or providers for services provided within 1 year of injury, excluding services that occurred in the first 6 weeks. Disability compensation was summed for 1 year post-injury. All costs from claims data were adjusted for inflation to 2005 US dollars using the Consumer Price Index for Medical Care (2002: 285.6; 2003: 297.1; 2004: 310.1; 2005: 323.2).(98)

Total outpatient costs included any procedures that took place during an outpatient visit with CPT-4 codes 00000-99999, HCPCS codes G (medical procedures), J (drugs), L (orthotic/prosthetic procedures), and LNI local codes representing healthcare services (e.g. pain evaluation, attendant services). Prescription drug costs included all costs reimbursed by L&I for filled prescription medications. Inpatient costs included all allowed costs for any service, treatment, or procedure that took place during hospitalization. Other workers' compensation costs were specific to benefits and costs for vocational assistance, employability assessments, worker transportation, medical devices, and other costs not included in outpatient services. Disability compensation is defined as the total wage-replacement benefits associated with the LBP claim and consists of 60-75% of average weekly wage and adjusted for marital status and dependents.

E. Covariates

Covariates were selected based on healthcare utilization models and current literature pertaining to LBP disability.(63, 65, 74) Covariates were ascertained from baseline D-RISC structured telephone interviews, medical chart reviews, and computerized claims data. D-RISC participants provided demographic information during baseline D-RISC interviews; variables included age, race/ethnicity, education, income, and marital status.

Workers rated their health status (aside from injury) on a Likert scale both for the year prior to the injury and at the time of the baseline interviews. Body mass index (BMI) was calculated from self-reported height and weight. Pain intensity refers to average pain in the last week, either from injury or other causes, on a 0-10 scale (higher scores indicating more pain).(80) The Roland-Morris disability questionnaire assesses LBP-specific disability on a 0-24 scale (higher scores reflecting higher levels of disability).(81, 82) Injury category was ascertained from medical record review by occupational health nurses and grouped as follows: 1) Mild sprain/strain and/or minor physical exam findings, including mildly decreased mobility, paravertebral tenderness, muscle spasm or tightness; 2) Major sprain/strain evidenced by substantial mobility without evidence of nerve injury or radiculopathy; 3) Evidence of radiculopathy with appropriate symptoms, including pain or tingling radiating down the leg, below the knee, or sensory loss, or clearly positive straight-leg raising test ≤45°; 4) Absent reflexes (knee or ankle), bladder complaints or motor abnormalities (including sensory loss or muscle weakness).[(83)]

The following psychosocial measures were ascertained at baseline D-RISC interviews: catastrophizing, a psychosocial health measure of coping response,(75) work fear-avoidance,(76) and mental health status from SF-36 (version 2, 1 week time frame).(77, 78)

Retrospective review of L&I administrative claims data allowed us to determine whether the worker had a previous compensable back claim. At baseline interviews, workers reported overall job satisfaction, physical demands at work,(66) and whether their employer offered accommodations for the injury (e.g., change in physical environment, tasks, work-schedule, job positions, or part-time work). Employment industry was determined according to the North American Industry Classification System.(79)

The type of first medical visit for the claim was obtained from L&I medical claims. This variable was categorized as primary care physician, occupational health physician, chiropractor, surgeon, emergency department, or other provider (including specialists and physical medicine).

F. Statistical analyses

Workers who received an early MRI were compared to workers whose care was consistent with guidelines. We used STATA/IC 10.1 for Macintosh (Stata Corp., College Station, TX) for all analyses. Worker characteristics were summarized using descriptive statistics, including frequencies (percentages) for categorical variables.

Descriptive analyses compared dichotomized proportions of utilization measures (e.g. received 1+ CT) between workers who received early MRI and those who did not, using χ^2 tests. The unadjusted mean number of procedures were compared between workers with early imaging and workers with imaging consistent with guidelines using *t*-tests; for interpretability, we converted units from the number of procedures or visits per worker to the number per 100 workers. Differences in unadjusted mean costs between workers with early imaging and workers whose imaging was consistent with guidelines were assessed using *t*-tests.

Modified Poisson regression with robust standard errors was used to estimate the adjusted relative risk (RR) of receiving 1 or more procedure for each utilization measure. This method is appropriate for estimating RR in prospective studies with binary outcomes and common base incidence.(84)

Two-part models were used to assess whether early imaging influences utilization of office visits (chiropractor, PT/OT, and office visits) and total costs (outpatient, inpatient, pharmacy, other workers' compensation, and disability compensation costs). The following explanation describes "costs" as the general outcome of interest; each cost component described above was analyzed using a two-part model, and the same analysis was conducted for office visits. The first part of this model uses multivariate logistic regression to estimate the probably of incurring any costs and the second part estimates the adjusted costs among workers who incurred costs using a generalized linear model (GLM) adjusting for covariates. GLMs have been shown to perform well when analyzing right-skewed and overdispersed cost data.(99-101) Box-Cox and modified Park Tests were used to evaluate GLM link and family.(102, 103) Goodness of fit (deviance) tests evaluated model fit.(99) The adjusted, or unconditional, mean cost for each worker, regardless of incurring any costs, was predicted by multiplying the probability of incurring cost by predicted conditional costs from the GLM specification.

The adjusted mean cost difference associated with early imaging was computed by estimating the regression-adjusted difference between costs for workers with early imaging and those without, using methods described by Afifi et al.(100) First, all workers were assigned to receive early imaging and individual costs are computed by multiplying estimated coefficients of the first and second parts of the model. The process is then repeated by setting all workers to receiving imaging 6 weeks after injury. The predicted effect of imaging for each individual is the difference in costs, and the adjusted mean difference in cost attributable to early imaging is the average over the population of workers. Bootstrap resampling methods were used to estimate the 95% confidence intervals of cost differences.

IV. RESULTS

From July 2002 to April 2004, 4354 workers were identified, of whom 49% agreed to participate in the D-RISC study, 27% could not be contacted, 3% were ineligible due to language limitations, and 21% declined to participate. Of the 2147 subjects who agreed to participate, 240 were excluded for lacking work disability compensation, and 22 others were excluded for other reasons. The final D-RISC sample of 1885 workers, compared with non-participants (N=1776), was slightly older (mean 39.4 vs. 38.2 years, $p<0.001$) and included more women (32% vs. 26%, $p<0.001$).(66) Workers who did not file a claim within 2 months after injury (N=55) were excluded from analyses. Workers whose medical chart review indicated absent reflexes (knee or ankle), bladder complaints or motor abnormalities (including sensory loss or muscle weakness) were excluded from these analyses (N=60). The final sample for this analysis consisted of 1770 workers.

Among the 1770 workers, 331(18.7%) received an MRI within 6 weeks of injury (early MRI). Table 3.1 displays characteristics of workers by early MRI status. Workers who received early MRI reported higher Roland scores, pain intensity, catastrophizing, and fear avoidance scores, poorer mental health status, heavier physical demands at work, and lack of accommodations for their injury at work (χ^2 test, $p<0.01$). A smaller proportion of workers who received an early MRI first sought chiropractic care (19.0%), compared to other workers (33.1%) ($p<0.01$). All subsequent analyses adjusted for all covariates listed in Table 3.1.

Table 3.1: Baseline characteristics of workers.

	MRI within 6 weeks of injury (N=331)	Consistent with guidelines (N=1439)	Sig
Age (at injury)			*
Under 24 yrs	24 (7.3)	166 (11.5)	
25-34 yrs	74 (22.4)	385 (26.8)	
35-44 yrs	116 (35.0)	420 (29.2)	
45-54 yrs	86 (26.0)	322 (22.4)	
Over 55 yrs	31 (9.4)	146 (10.1)	
Sex			*
Female	90 (27.2)	478 (33.2)	
Male	241 (72.8)	961 (66.8)	
Race/ethnicity			
Non-Hispanic white	250 (75.5)	979 (68.0)	
Non-Hispanic non-white	33 (10.0)	205 (14.2)	
Hispanic non-white	31 (9.4)	170 (11.8)	
Hispanic white	10 (3.0)	37 (2.6)	
Education			
Less than high school	43 (13.0)	192 (13.3)	
High school diploma/GED	124 (37.5)	478 (33.2)	
Some college	144 (43.5)	638 (44.3)	
College degree	20 (6.0)	130 (9.0)	
Household income ($)			
< 30,000	114 (34.4)	593 (41.2)	

	MRI within 6 weeks of injury (N=331)	Consistent with guidelines (N=1439)	Sig
30-45,000	85 (25.7)	354 (24.6)	
45-70,000	88 (26.6)	311 (21.6)	
>70,000	36 (10.9)	126 (8.8)	
Marital status			
Married	174 (52.6)	730 (50.7)	
Living with partner	48 (14.5)	203 (14.1)	
Divorced	71 (21.5)	267 (18.6)	
Other	38 (11.5)	236 (16.4)	
Body Mass Index (BMI)			
Normal <25	84 (25.4)	446 (31.0)	
Overweight 25-29	132 (39.9)	551 (38.3)	
Obese 30-34	77 (23.3)	285 (19.8)	
Very obese >34	34 (10.3)	119 (8.3)	
Health in year before injury			
Excellent	86 (26.0)	325 (22.6)	
Very good	111 (33.5)	525 (36.5)	
Good	95 (28.7)	436 (30.3)	
Fair/Poor	39 (11.8)	150 (10.4)	
Health status at time of interview			
Excellent	66 (19.9)	283 (19.7)	
Very good	109 (32.9)	522 (36.3)	
Good	110 (33.2)	454 (31.5)	
Fair/poor	44 (13.3)	179 (12.4)	
Roland-Morris score[a] (0-24)			**
Low (0-6)	35 (10.6)	406 (28.2)	
Moderate (7-12)	109 (32.9)	564 (39.2)	
High (13-18)	187 (56.5)	466 (32.4)	
Very high (~24)			
Pain intensity[b] (0-10)	13 (3.9)	409 (28.4)	**
Low/no pain (0-3)	43 (13.0)	331 (23.0)	
Mild pain (4-6)	111 (33.5)	401 (27.9)	
Moderate/high pain (7-10)	164 (49.5)	298 (20.7)	
Injury category			**
Mild sprain/strain and/or minor physical exam findings	98 (29.8)	906 (63.3)	
Major sprain/strain evidenced by substantial immobility	69 (21.0)	308 (21.5)	
Evidence of radiculopathy	162 (49.2)	217 (15.2)	
SF-36 Mental health score[c]			**
2 SD below population mean	80 (24.2)	176 (12.2)	
1-2 SD below population mean	94 (28.4)	286 (19.9)	
1 SD below population mean	92 (27.8)	352 (24.5)	
At or above population mean	65 (19.6)	623 (43.3)	
Catastrophizing[c] (0-4)			**
Low (<1)	39 (11.8)	373 (25.9)	
Moderate (1-2.9)	172 (52.0)	782 (54.3)	
High (3-4)	120 (36.3)	284 (19.7)	

	MRI within 6 weeks of injury (N=331)	Consistent with guidelines (N=1439)	Sig
Work fear-avoidance[e] (0-6)			**
Low (0-2.9)	29 (8.8)	325 (22.6)	
Moderate (3-4.9)	84 (25.4)	489 (34.0)	
High (5-5.9)	133 (40.2)	398 (27.7)	
Very high (6)	85 (25.7)	227 (15.8)	
Offered job accommodation for disability			**
Yes	116 (35.0)	691 (48.0)	
No	208 (62.8)	732 (50.9)	
1+ previous compensable back claims			*
Yes	81 (24.5)	260 (18.1)	
No	1169 (81.2)	250 (75.5)	
Job satisfaction			
Not at all	15 (4.5)	86 (6.0)	
Not too satisfied	28 (8.5)	129 (9.0)	
Somewhat satisfied	143 (43.2)	594 (41.3)	
Very satisfied	145 (43.8)	626 (43.5)	
Industry			
Trade/transportation	76 (23.0)	358 (24.9)	
Natural resources	9 (2.7)	76 (5.3)	
Construction	69 (20.8)	250 (17.4)	
Manufacturing	36 (10.9)	104 (7.2)	
Management	57 (17.2)	229 (15.9)	
Education/health	45 (13.6)	227 (15.8)	
Hospitality	39 (11.8)	195 (13.6)	
Physical demands at work			**
Light	52 (15.7)	297 (20.6)	
Medium	99 (29.9)	462 (32.1)	
Heavy	76 (23.0)	350 (24.3)	
Very heavy	100 (30.2)	324 (22.5)	
Type of first medical visit			**
Primary care	162 (48.9)	624 (43.4)	
Occupational medicine	17 (5.1)	39 (2.7)	
Chiropractor	63 (19.0)	477 (33.1)	
Surgeon	11 (3.3)	25 (1.7)	
Emergency room/clinic	71 (21.5)	250 (17.4)	
Other	7 (2.1)	24 (1.7)	

Values are N (%) and significance values indicate results from χ^2 tests.
*p<0.05; *p<0.01.
Frequency counts do not always sum to total because of missing responses or rounding.
[a] Roland-Morris disability questionnaire measures physical functioning relating to back pain.(81, 82)
[b] Any pain in the last week, scale ranges from 0-10.(80)
[c] SF-36 MH, Short Form-36 version 2 Mental Health scale.(77, 78)
[d] Mean of responses to 3 questions from the Pain Catastrophizing scale.(75)
[e] Mean of responses to two questions from the Fear-Avoidance Beliefs Questionnaire work scale.(76)

Table 3.2 shows healthcare utilization patterns in the year after injury (excluding the first 6 weeks), by early MRI status. Comparing workers with early MRI to those without, 30% more workers with early MRI received at least one lumbosacral injection, 17% more had lumbar surgery, 48% more had at least one prescription medication, 45% more had at least one PT/OT visit, and 54% more had at least one outpatient visit after the first six weeks of symptoms (unadjusted proportions, χ^2 tests p<0.01, Table 3.2). Unadjusted means suggest that workers with early MRI had significantly more procedures (lumbosacral radiograph, injection, or surgery), prescriptions, and PT/OT and outpatient visits (*t*-test p<0.01, Table 3.2).

Table 3.2: Unadjusted healthcare utilization in the year following occupational low back injury among workers with early imaging and workers with imaging consistent with guidelines.

	One or more procedure/visit[a]			Number of procedures or visits, per 100 workers[b]		
	MRI within 6 weeks of injury N (%)	Consistent with guidelines N (%)	Sig	MRI within 6 weeks of injury Mean (SD)	Consistent with guidelines Mean (SD)	Sig
MRI	76 (23.0)	255 (17.7)	*	27 (54)	21 (49)	*
CT	12 (3.6)	26 (1.8)	*	5 (25)	2 (14)	*
Radiograph	32 (9.7)	83 (5.8)	**	13 (5)	7 (31)	**
Injection	122 (36.9)	97 (6.7)	**	77 (120)	16 (68)	**
Surgery	64 (19.3)	32 (2.2)	**	21 (45)	3 (18)	**
Prescription	227 (68.6)	293 (20.4)	**	898 (1326)	215 (707)	**
Chiropractic visit	105 (31.7)	544 (37.8)	*	1034 (2213)	879 (1949)	
PT/OT visit	248 (74.9)	427 (29.7)	**	1475 (1871)	506 (1252)	**
Outpatient visit	822 (90.0)	524 (36.4)	**	831 (722)	236 (525)	**
Total (N)	331	1439				

Procedures listed occurred from six weeks after injury to one year after injury.
[a]Values reported are the percent of workers who received at least one procedure (e.g. MRI, CT, radiograph, injection, or prescription) or office visit in the year following low-back injury.
[b]Values reported are the mean (standard deviation) of the number of procedures (e.g. number of MRIs) or office visits, per 100 workers.
Significance shows results of unadjusted comparison between early MRI and others using χ^2 or t-tests; *p<0.05; **p<0.01

Table 3.3 shows the proportion of workers with non-zero costs (columns 2-3) and unadjusted mean costs among all workers (column 5-6). A greater proportion of workers with early imaging had non-zero costs for all measures except disability compensation, wherein the majority of all workers had non-zero costs, regardless of early imaging (Table 3.3). Unadjusted mean costs were significantly higher among workers with early imaging for all measures. Total outpatient expenditures averaged $4,713 for workers with early MRI, compared to $1,816 for other workers. Workers with early imaging received an average of $10,540 in disability compensation in the year following injury, roughly five times more than workers with late or no MRI ($2,780).

Table 3.3: Unadjusted costs in the year following occupational low back injury among workers with early imaging and workers with imaging consistent with guidelines.

	Proportion with non-zero costs			Unadjusted mean costs		
	MRI within 6 weeks of injury N (%)	Consistent with guidelines N (%)	Sig	MRI within 6 weeks of injury Mean (SD)	Consistent with guidelines Mean (SD)	Sig
Outpatient services	314 (94.86)	900 (62.54)	**	$4,713 (4,625)	$1,816 (3,601)	**
Inpatient services	155 (46.83)	223 (15.5)	**	1,242 (2,249)	253 (954)	**
Prescription drugs	227 (68.58)	293 (20.36)	**	399 (771)	101 (390)	**
Disability compensation	325 (98.19)	1425 (99.03)		10,540 (10,966)	2,780 (6,080)	**
Other workers' compensation costs[a]	295 (89.12)	662 (46.00)	**	2,185 (3,207)	590 (1,975)	**
Total	331	1439				

Values are counts (percentages and unadjusted means (standard deviations) as indicated. Costs refer to total reimbursed amounts for procedures and visits that occurred from six weeks after injury to one year after injury. Significance shows results of comparison between early MRI and others using χ^2 or t-tests; *p<0.05; **p<0.01

Table 3.4 shows results from modified Poisson regression models, adjusting for sociodemographic, health, injury, psychosocial, employment characteristics, and type of first medical visit, which estimate the likelihood of receiving at least one procedure, comparing workers with early MRI to other workers. Workers who received an early MRI were significantly less likely to receive lumbar MRI (RR: 0.58, 95% CI: 0.46-0.74) or CT

(RR: 0.40, 95% CI: 0.17-0.91) between 6 weeks and 1 year following injury, compared to workers without early imaging. Workers with early imaging were 3 times more likely to receive surgery (RR: 3.00, 95% CI: 1.81-4.99) and over 2 times more likely to receive a lumbosacral injection (RR: 2.27, 95% CI: 1.69-3.04) in the year following injury than other workers, adjusting for covariates. Early imaging was also associated with a greater likelihood of receiving any prescription medication, PT/OT visits, or outpatient visits (Table 3.4).

Table 3.4. Likelihood of utilization among workers with early imaging and those whose imaging was consistent with guidelines.

	Likelihood of at least one procedure or visit[a]	
	RR (95% CI)	**Sig**
MRI	0.58 (0.46, 0.74)	**
CT	0.40 (0.17, 0.91)	*
Radiograph	0.84 (0.54, 1.31)	
Injection	2.27 (1.69, 3.04)	**
Surgery	3.00 (1.81, 4.99)	**
Prescription	1.64 (1.42, 1.88)	**
Chiropractic visit	1.03 (0.88, 1.21)	
PT/OT visit	1.46 (1.30, 1.63)	**
Outpatient visit	1.44 (1.32, 1.57)	**

[a]Adjusted relative risk (RR) from modified Poisson regression indicating the likelihood of workers who received an early MRI to receive at least one of the listed procedures, controlling for all covariates listed in Table 3.1. Significance shows results of comparison between early MRI and late/no MRI using Wald tests; *p<0.05; **p<0.01

Table 3.5 shows results from the covariate-adjusted two-part model analyses, which estimated the difference in office visits and costs associated with early imaging. Log link and Poisson family were chosen as model specifications for outpatient visits and log link and Gamma family were used for cost models; Box-Cox and modified Park Tests supported these selections.(102, 103) The estimated mean number of office visits was higher for workers with early imaging for PT/OT (difference 4.32 (SD: 1.13) visits, p<0.01) and outpatient visits (estimated difference 2.50 (SD: 0.36) visits, p<0.01).

Workers with early imaging did not have significantly more office visits for chiropractic care (Table 3.5).

Estimated differences in mean costs were significantly different from zero for outpatient and inpatient services, disability compensation, and other workers' compensation costs (Table 3.5, p<0.01). The adjusted mean difference in outpatient costs associated with early imaging was $1,026 (95% CI: 568-1,483), and the adjusted mean difference for inpatient services was $400 (95% CI: 189-611). The adjusted mean disability compensation for workers with early MRI was 97.9% greater than workers with imaging consistent with guidelines (difference $3,321; 95% CI: 1,533-5,110). The estimated mean difference in prescription drug costs associated with early imaging was not significantly different from zero (p=0.055).

Table 3.5: Estimated healthcare utilization and costs associated with early imaging, results from covariate-adjusted two-part models.

	MRI within 6 weeks of injury	Consistent with guidelines	Difference associated with early imaging	
Office visits				
Chiropractic	9.10 (0.55)	8.73 (1.47)	-0.37[b] (1.68)	
PT/OT	5.92 (0.37)	10.23 (0.80)	4.32 (1.13)	**
Outpatient	2.93 (0.15)	5.44 (0.30)	2.50 (0.36)	**
Costs				
Outpatient services	$3,183 (201)	$2,158 (130)	$1,026 (288)	**
Inpatient services	726 (97)	326 (35)	400 (118)	**
Prescription drugs	146 (15)	212 (24)	66[b] (35)	*
Disability compensation	6,715 (1,239)	3,394 (523)	3,321 (913)	**
Other workers' compensation costs[a]	1,470 (162)	721 (67)	749 (200)	**

Values are adjusted mean number of visits or costs per worker, and bootstrapped standard errors (in parentheses).
[a] Other workers' compensation costs were specific to occupational injuries and included costs included reimbursement for vocational (return-to-work) assistance, employability assessments, worker transportation, medical devices, and other costs not included in outpatient care costs.
[b] Relative standard error >0.3, indicating that the estimate is unstable.
Significance shows results of comparison between early MRI and late/no MRI using Wald tests; *p<0.05; **p<0.01

V. DISCUSSION

Despite clinical guidelines recommendation that advanced imaging, such as MRI, should not take place in the first 4-6 weeks of LBP symptoms, we found nearly 1 in 5 workers with LBP received MRI within this time frame. This early imaging was associated with increased risk of surgery, injections, PT/OT and outpatient visits, but decreased risk of subsequent imaging, including lumbar MRI and CT, by 42% and 60%, respectively.

Other studies have shown that use of early imaging may be associated with higher utilization and costs.(56, 58, 60) A study that randomized patients to receive early imaging and delayed, selective imaging, showed a higher likelihood of outpatient visits among those with early imaging. The total number of visits did not differ between the groups, in contrast to our study that found a significant impact on the amount of subsequent utilization. In another RCT, Jarvik and colleagues found that LBP patients randomized to receive rapid MR imaging engaged in more consultation visits and had a higher mean cost of healthcare services, compared to the radiography patients, although this result was not statistically significant.(56) In an analysis of workers' compensation claims, Webster and colleagues found that early MRI was associated with higher mean medical costs compared to not receiving an MRI at all ($2,779 vs. $21,921), however, their analysis does not include workers who received an MRI after the first 6 weeks of care, so results may be biased. Also, these estimates did not adjust for individual-level factors, such as pain intensity or physical functioning.(61)

We observed a greater likelihood of surgery among those with early imaging, after adjusting for covariates. This finding supports earlier research (39, 56, 61) and others have suggested that early imaging may be used for planning of subsequent care, such as surgery or injections.(61) The increased risk of PT/OT and outpatient visits, and the increased number of visits attributed to early imaging was associated with substantial costs. We showed that for workers with acute LBP, early imaging was significantly associated with increased costs by approximately $1,026 for outpatient services, $400 for inpatient services, $3,321 for disability compensation, and $749 for workers' compensation costs, such as vocational assistance.

The financial impact of early imaging could be offset by improved health outcomes, however, studies suggest that early imaging does not result in significant, cost-effective improvements in pain, functioning, or health status, compared to individuals who receive usual care.(56, 58) The excess costs associated with early imaging are not trivial, and adherence to evidence-based guidelines could result in substantial cost savings for payers, such as workers' compensation programs, presumably without deleterious effects to patients.'

The strength of this study included the ability to follow a large, population-based cohort of workers with LBP and collect detailed information about each worker's healthcare experience. The rich combination of independent and dependent variables available from administrative claims and interview data represents a substantial strength of this study and enabled numerous confounders, including pain, functioning, and baseline health status, to be taken into account in analyses.

This study was conducted from the payer's perspective. Workers' compensation claimants are not responsible for deductibles out-of-pocket expenses, so our estimates approximate the total direct costs of the care provided. Many indirect costs, such as the transportation costs to/from appointments, are reimbursed and therefore accounted for in the "other workers' compensation costs" category. Nonetheless, workers may seek LBP treatment that is not covered by workers' compensation, such as acupuncture, in which case those costs would not be included in this analysis.

This study has several limitations. First, although this study used a large, population-based sample, subjects were restricted to Washington State workers' compensation claimants with non-severe injuries that resulted in ≥4 days of compensated lost work time. As such, results may not be generalized beyond a working population with compensable, non-traumatic occupational injuries. Nonetheless, non-specific occupational LBP is a particularly common condition (104), enabling the results to be applicable to a relatively large population. Second, given the observational nature of this study, the possibility of residual confounding by unmeasured variables may exist, despite the availability of numerous individual-level, independent variables. Third, the design and scope of this study limited our ability to evaluate providers' reasons for ordering MRI or the appropriateness of imaging. These are important topics in healthcare utilization and cost research and should be addressed by future research.

Despite these limitations, this study provides valuable insight regarding the impact of early imaging on reimbursed healthcare costs and utilization among workers' compensation claimants. Adherence to evidence-based guidelines for early imaging is crucial to curb unnecessary resource use, associated costs, and the potential for adverse outcomes. This study shows that contrary to recommendations, early imaging is a common element of routine care for workers' compensation claimants with non-specific, uncomplicated LBP and leads to increases in utilization and costs. This cascade effect could be avoided through promotion and adherence to clinical guidelines for early imaging.

Chapter 4. Early imaging for acute low back pain: 1-year health and disability outcomes among Washington State workers

I. CHAPTER SUMMARY

Summary of background data. Use of early diagnostic MRI for low back pain (LBP) contributes to increasing healthcare costs but may not lead to better outcomes, compared to delayed imaging. In the worker's compensation system, LBP is a common and costly condition. This research examines the association between early MRI among workers with LBP and health outcomes (pain intensity, Roland-Morris disability, and SF-36 scores) and disability status 1 year after injury.

Methods. This population-based, prospective cohort study of Washington State workers' compensation claimants with non-specific LBP used administrative claims and interview data. Multivariable regression methods were used to estimate the change in health outcome scores, the relative risk of disability at 1 year, and the rate of recovery 1 year after injury.

Results. Of 1,226 participants, 331(18.6%) received early MRI. Most (77.9%) had mild/major sprains; 22.1% had radiculopathy. After adjusting for covariates, early imaging was not associated with substantial differences in 1-year health outcomes for sprains or radiculopathy. For workers with mild/major sprain, early imaging was associated with a 2-fold increase in the likelihood of work disability benefits at 1 year (adjusted RR: 2.03, 95%CI: 1.33-3.11). Early imaging was not associated with an increased risk of long-term disability for workers with radiculopathy (adjusted RR: 1.31, 95%CI: 0.84-2.05). For both groups, early MRI was associated with longer disability duration ($p<0.001$).

Conclusions. Among workers with LBP, early MRI does not result in better health outcomes and is associated with increased likelihood of disability and disability duration. Our findings suggest that adherence to evidence-based guidelines is an important factor in ensuring workers receive the highest quality care for occupational injuries.

II. INTRODUCTION

Due to recent advancements in technology and radiological research, use of advanced diagnostic imaging has been increasing rapidly.(47, 48) Among injured workers, the use of complex diagnostic testing nationally rose 57% from 1996 to 2002.(50) It remains unclear whether use of advanced imaging, such as magnetic resonance imaging (MRI), contributes to better health and disability outcomes in injured workers with low back pain (LBP).

Randomized controlled trials suggest that early imaging for LBP may contribute to increased healthcare utilization and costs, but not contribute to treatment planning or provide diagnostic information of enough value to justify additional costs.(60) Further, use of early imaging may not be associated with improved outcomes.(56, 58) In fact, early imaging may deleteriously affect a patient's emotional and psychological well-being.(33) A "cascade of care" may occur following early imaging, in which conditions not attributable to the LBP (and potentially asymptomatic) may be discovered and unnecessarily treated.

To address the potential over- or misuse of early imaging for LBP, evidence-based guidelines discourage routine imaging in the first 4-6 weeks of LBP for patients without signs of neurologic impairment or other complications.(2, 44, 52, 53) The majority of LBP patients typically do not bear these indications, which include recent significant trauma, or milder trauma (age >50), unexplained weight loss or fever, immunosuppresion, history of cancer, intravenous drug use, prolonged use of corticosteroids, osteoporosis, age >70, or focal neurologic deficit with progressive or disabling symptoms.(8, 44, 105)

It is prudent to consider the health outcomes associated with early imaging within the workers' compensation population, where LBP is the most prevalent and costly occupational injury.(69, 106, 107) Use of MRI for LBP cases is a common and expensive component of workers' compensation claims, so much so that, following a statutory directive by the state legislature, the Washington State Department of Labor and Industries (L&I) recently instituted utilization review processes to address inappropriate use of MRI for LBP.(108)

This research evaluates the association of early imaging on health and disability status one year following acute low back injury, independent of baseline characteristics, among a population-based sample of Washington workers' compensation claimants.

III. METHODS

A. Design

This prospective observational cohort study used administrative claims, medical billing, and survey data to compare health and disability outcomes in injured workers who received an MRI consistent with guidelines (after six weeks or not at all) and those who received an early MRI (within six weeks of injury).

B. Data Source

The Washington workers' compensation program comprises approximately two-thirds of all non-federal workers in the state. The Washington workers' compensation Disability Risk Identification Study Cohort (D-RISC) study identified workers with new claims for occupational back injuries filed between July 2002 and April 2004. Details of the D-RISC study have been reported elsewhere.(65-67) Participants were restricted to adults (>18 years) with an accepted claim, with at least 4 missed workdays due to injury, and no hospitalization following the injury.

Trained interviewers performed computer-assisted telephone interviews at baseline and after one year. Baseline interviews were conducted 2-3 weeks (median 18 days, range 10-58 days) after filing a workers' compensation claim. Follow-up interviews were conducted one year (median 343 days, range 332-395 days) after baseline interview. Interviews included questions regarding overall and injury-specific health status, work, and personal characteristics. The University of Washington Institutional Review Board approved this study. All participants provided informed consent and were provided $10 compensation for participation in each interview.

The Washington State L&I provided workers' compensation administrative claims data for D-RISC participants. These data include the date of injury, wage replacement benefits, and job type. D-RISC survey and L&I administrative data were linked with workers' compensation medical bill data, which included provider type, dates, and types of procedures.

C. Health Measures

The Roland-Morris Disability Questionnaire (RDQ) consists of 24 yes/no items to assess the physical disability due to LBP.(81) The summary score ranges from 0 (no disability) to 24 (severe disability). The RDQ is reported as reliable and responsive to change and is frequently used to detect short-term changes in back pain and related disability.(81, 109) The Short Form (36-Item) Health Survey version 2 (SF-36®) is a generic health profile that measures dimensions of health related quality of life, each scored from 0 (worst) to 100 (best). Raw scores were converted using a norm-based scoring system, which uses a mean of 50 and a standard deviation of 10 in the general US population for each scale (range 0-100).(77, 78) SF-36 Role Physical and Physical Function scales have been shown to be predictive of long-term disability among workers in this cohort.(110) Workers' pain intensity was evaluated at each interview using an adaptation of the pain intensity subscale of the Graded Chronic Pain Scale, which has been shown to be reliable, valid, and appropriate for acute or chronic LBP.(111, 112) The score ranges from 0 to10, with 0 indicating "no pain" and 10 indicating "pain as bad as could be."(113)

D. Disability Measures

Administrative claims data was used to determine the cumulative number of days each worker received wage replacement benefits and disability status one year after claim receipt (on/off disability). For the purposes of this study, a worker was considered to be "on disability" if receiving benefits for missing work due to work-related low back injury. All follow-up times are right-censored at 365 days, the duration of this study. In addition, workers were asked several detailed questions in follow-up interviews about their work pattern since their injury. If workers were not working at one year, they were asked whether the primary reason was their injury.

E. Covariates

Covariates included in all analyses were selected *a priori*, informed by health services utilization models and current literature pertaining to LBP disability.(63, 65, 74) Covariates were ascertained at baseline from D-RISC interviews (sociodemographic, clinical, psychosocial, and employment variables), medical chart reviews (injury severity), administrative data (age, history of previous claims, industry), or medical bills (type of first medical visit).

D-RISC participants provided demographic information that included race/ethnicity, education, income, and marital status. Body mass index (BMI) was calculated from self-reported height and weight. Workers rated their health status (aside from injury), categorized on a Likert scale, for the year before injury and at the time of the interview.

Mental health status was measured using the SF-36 and scored based on U.S. population norms.(77, 78) Catastrophizing, a psychosocial health measure of coping response, was categorized into three levels: low, moderate, and high.(75) Work fear-avoidance was assessed by averaging responses to two items from the Fear-Avoidance Beliefs Questionnaire and categorized as very low, low-moderate, high and very high.(76)

L&I claims data were used to determine whether the worker had a previous compensable back claim. In interviews, workers reported overall job satisfaction and whether their employer offered accommodations for the injury. Employment industry was determined according to the North American Industry Classification System.(79) Physical demands were self-reported as sedentary/light, medium, heavy, or very heavy, based on typical work activities.(66)

The type of first medical visit was obtained from the medical bill database. This variable was categorized as primary care, occupational medicine, chiropractor, surgeon, emergency department, or other provider (including specialists and physical medicine). Review of medical records by occupational health nurses provided a clinical categorization of injury type; categories included mild/major sprain or strain, evidence of radiculopathy, or absent reflexes.(83)

F. Statistical analysis

Workers who received no imaging, or received MRI after the initial six weeks of LBP symptoms were considered as receiving imaging consistent with guidelines. Workers who received MRI within six weeks of injury were categorized as receiving early imaging. This cutoff value reflects clinical guidelines, which recommend waiting six weeks before imaging.(2, 44, 52, 53, 71) Because LBP complicated by radiated pain (radiculopathy, sciatica) may be interpreted as a red flag for imaging (114), analyses were run separately for cases with mild/major sprains and for those with radiculopathy.

Baseline data on workers were reported using descriptive statistics for all covariates and outcome measures. Analyses were performed using STATA/IC 10.1 for Macintosh (Stata Corp., College Station, TX).

The association between early imaging and health outcome measures (RDQ, pain, or SF-36) was assessed two ways. First, unadjusted differences in health scores at one year were assessed using t-tests. Second, adjusted differences were evaluated using multivariable linear regression models that included covariates and baseline values for each outcome of interest (e.g. baseline pain score in the pain model). The relative risk (RR) of receiving wage replacement benefits or not working due to injury was estimated using modified Poisson regression with robust standard errors, comparing workers whose imaging was consistent with guidelines and those who received early imaging.(84) To assess the bivariate relationship between time on disability for workers with imaging consistent with guidelines and those with early imaging, the Log Rank test for equality in survival functions and the Wilcoxon (Breslow) test were used. Multivariable Cox regression analysis controlled for covariates and baseline pain and RDQ. Hazard ratios (HRs) represent the risk of a shorter time on disability; so a HR<1 indicates increased disability duration. The proportional hazards assumption was tested and confirmed for all covariates.

IV. RESULTS

Of the 4,354 claimants identified by the D-RISC study, 49.3% agreed to participate, 27.1% could not be contacted, 20.9% declined, and 8.8% were ineligible due to language limitations, lacked disability compensation or were excluded for other reasons (e.g.

incomplete records). D-RISC subjects (N=1,885) differed slightly from the non-participants in age, gender, receiving compensation at one year, and number of days on disability.(66) For this study, 566 workers did not complete follow-up interviews and were not included in this analysis. Those who did not complete the follow-up interview were younger and included more Hispanic and unmarried workers with lower education and income ($p<0.01$) than cases who completed both interviews. An additional 41 workers with more than 2 months time between claim receipt and interview were excluded. In order to focus on workers with less severe injuries, 45 workers whose medical record review indicated severe injury (absent reflexes, bladder complaints, or motor abnormalities) and 7 workers who lacked injury severity information were excluded.

Of the final sample of 1,226 eligible study participants, 228 (18.6%) received an MRI within six weeks of injury. Most workers (77.9%) had injuries that were described as mild/major sprains; 22.1% of workers' medical records indicated evidence of radiculopathy. Significantly more workers with radiculopathy received early imaging compared to workers with mild/major sprains (39% vs. 13%, $p<0.01$). Table 4.1 describes characteristics of workers by early imaging, stratified by injury type. For both categories of injury, sociodemographic characteristics did not differ by early imaging; workers with early imaging were, however, more likely to have poorer scores for RDQ, pain, and psychosocial characteristics than workers who did not ($p<0.01$).

Table 4.1: Demographic, work, clinical, and health history characteristics of study subjects.

	Mild or major sprain/strain			Radiculopathy		
	MRI within 6 weeks (N=121) N (%)	**Consistent with guidelines (N=834)** N (%)	**Sig**	**MRI within 6 weeks (N=107)** N (%)	**Consistent with guidelines (N=164)** N (%)	**Sig**
Age (at injury)						
Under 24 yrs	8 (6.6)	83 (10.0)		5 (4.7)	14 (8.5)	
25-34 yrs	30 (24.8)	211 (25.3)		22 (20.6)	29 (17.7)	
35-44 yrs	40 (33.1)	250 (30.0)		37 (34.6)	47 (28.7)	
45-54 yrs	33 (27.3)	199 (23.9)		30 (28.0)	55 (33.5)	
Over 55 yrs	10 (8.3)	91 (10.9)		13 (12.1)	19 (11.6)	
Sex						*
Female	36 (29.8)	280 (33.6)		30 (28.0)	68 (41.5)	
Male	85 (70.2)	554 (66.4)		77 (72.0)	96 (58.5)	
Race/ethnicity						
Non-Hispanic, white	92 (76.0)	595 (71.3)		82 (76.6)	118 (72.0)	
Non-Hispanic, non-white	12 (9.9)	118 (14.1)		11 (10.3)	19 (11.6)	
Hispanic	14 (11.6)	103 (12.4)		13 (12.1)	23 (14.0)	
Education						
Less than high school	12 (9.9)	89 (10.7)		10 (9.3)	26 (15.9)	
High school diploma/GED	49 (40.5)	266 (31.9)		40 (37.4)	49 (29.9)	
Some college	50 (41.3)	391 (46.9)		52 (48.6)	72 (43.9)	
College degree	10 (8.3)	88 (10.6)		5 (4.7)	17 (10.4)	
Household income ($)						
< 30,000	38 (31.4)	316 (37.9)		38 (35.5)	57 (34.8)	
30-45,000	34 (28.1)	203 (24.3)		20 (18.7)	49 (29.9)	
45-70,000	31 (25.6)	207 (24.8)		35 (32.7)	36 (22.0)	
>70,000	15 (12.4)	85 (10.2)		11 (10.3)	15 (9.1)	
Marital status						
Married	70 (57.9)	452 (54.2)		62 (57.9)	89 (54.3)	
Living with partner	19 (15.7)	115 (13.8)		12 (11.2)	20 (12.2)	
Divorced	23 (19.0)	151 (18.1)		23 (21.5)	33 (20.1)	
Other	9 (7.4)	115 (13.8)		10 (9.3)	22 (13.4)	
Body Mass Index (BMI)						
Normal <25	28 (23.1)	262 (31.4)		25 (23.4)	46 (28.0)	
Overweight 25-29	50 (41.3)	321 (38.5)		42 (39.3)	59 (36.0)	
Obese 30-34	28 (23.1)	166 (19.9)		29 (27.1)	32 (19.5)	
Very obese >34	14 (11.6)	65 (7.8)		10 (9.3)	22 (13.4)	
Health in year before injury						
Excellent	31 (25.6)	186 (22.3)		24 (22.4)	42 (25.6)	
Very good	43 (35.5)	320 (38.4)		39 (36.4)	51 (31.1)	
Good	36 (29.8)	249 (29.9)		29 (27.1)	55 (33.5)	
Fair/Poor	11 (9.1)	77 (9.2)		15 (14.0)	16 (9.8)	
Health status at baseline interview			*			
Excellent	23 (19.0)	159 (19.1)		21 (19.6)	36 (22.0)	
Very good	42 (34.7)	329 (39.4)		39 (36.4)	51 (31.1)	

	Mild or major sprain/strain			Radiculopathy		
	MRI within 6 weeks (N=121) N (%)	**Consistent with guidelines (N=834)** N (%)	**Sig**	**MRI within 6 weeks (N=107)** N (%)	**Consistent with guidelines (N=164)** N (%)	**Sig**
Good	41 (33.9)	257 (30.8)		30 (28.0)	54 (32.9)	
Fair/poor	13 (10.7)	89 (10.7)		17 (15.9)	23 (14.0)	
Roland-Morris score[a] (0-24)			**			**
Low (0-6)	7 (5.8)	271 (32.5)		2 (1.9)	19 (11.6)	
Moderate (7-12)	20 (16.5)	199 (23.9)		13 (12.1)	40 (24.4)	
High (13-18)	42 (34.7)	223 (26.7)		33 (30.8)	51 (31.1)	
Very high (~24)	52 (43.0)	141 (16.9)		59 (55.1)	54 (32.9)	
Pain intensity[b] (0-10)			**			**
Low/no pain (0-3)	18 (14.9)	269 (32.3)		5 (4.7)	30 (18.3)	
Mild pain (4-6)	47 (38.8)	314 (37.6)		34 (31.8)	62 (37.8)	
Moderate/high pain (7-10)	56 (46.3)	251 (30.1)		68 (63.6)	72 (43.9)	
SF-36 Role Physical score[c]			**			**
2 SD below pop'n mean	79 (65.3)	197 (23.6)		77 (72.0)	73 (44.5)	
1-2 SD below pop'n mean	31 (25.6)	192 (23.0)		24 (22.4)	43 (26.2)	
1 SD below pop'n mean	9 (7.4)	192 (23.0)		5 (4.7)	27 (16.5)	
At or above pop'n mean	2 (1.7)	253 (30.3)		1 (0.9)	21 (12.8)	
SF-36 Physical Functioning score[c]			**			**
2 SD below pop'n mean	63 (52.1)	161 (19.3)		73 (68.2)	75 (45.7)	
1-2 SD below pop'n mean	32 (26.4)	181 (21.7)		17 (15.9)	35 (21.3)	
1 SD below pop'n mean	21 (17.4)	216 (25.9)		12 (11.2)	34 (20.7)	
At or above pop'n mean	5 (4.1)	276 (33.1)		5 (4.7)	20 (12.2)	
SF-36 Mental health score[c]			**			**
2 SD below pop'n mean	24 (19.8)	90 (10.8)		28 (26.2)	29 (17.7)	
1-2 SD below pop'n mean	30 (24.8)	155 (18.6)		34 (31.8)	34 (20.7)	
1 SD below pop'n mean	35 (28.9)	203 (24.3)		31 (29.0)	39 (23.8)	
At or above pop'n mean	32 (26.4)	386 (46.3)		14 (13.1)	62 (37.8)	
Catastrophizing[d] (0-4)			**			*
Low (<1)	17 (14.0)	243 (29.1)		10 (9.3)	28 (17.1)	
Moderate (1-2.9)	71 (58.7)	438 (52.5)		57 (53.3)	97 (59.1)	
High (3-4)	33 (27.3)	153 (18.3)		40 (37.4)	39 (23.8)	
Work fear-avoidance[e] (0-6)			**			*
Low (0-2.9)	10 (8.3)	179 (21.5)		9 (8.4)	36 (22.0)	
Moderate (3-4.9)	34 (28.1)	291 (34.9)		27 (25.2)	51 (31.1)	
High (5-5.9)	47 (38.8)	222 (26.6)		43 (40.2)	48 (29.3)	
Very high (6)	30 (24.8)	142 (17.0)		28 (26.2)	29 (17.7)	
Offered job accommodation for disability			**			
Yes	41 (33.9)	426 (51.1)		37 (34.6)	74 (45.1)	
No	77 (63.6)	401 (48.1)		66 (61.7)	88 (53.7)	
1+ previous compensable back claims			*			
Yes	34 (28.1)	152 (18.2)		23 (21.5)	32 (19.5)	
No	87 (71.9)	677 (81.2)		84 (78.5)	132 (80.5)	

	Mild or major sprain/strain			Radiculopathy		
	MRI within 6 weeks (N=121) N (%)	**Consistent with guidelines (N=834)** N (%)	**Sig**	**MRI within 6 weeks (N=107)** N (%)	**Consistent with guidelines (N=164)** N (%)	**Sig**
Job satisfaction						
Not at all	5 (4.1)	46 (5.5)		5 (4.7)	7 (4.3)	
Not too satisfied	10 (8.3)	69 (8.3)		9 (8.4)	16 (9.8)	
Somewhat satisfied	58 (47.9)	350 (42.0)		42 (39.3)	69 (42.1)	
Very satisfied	48 (39.7)	368 (44.1)		51 (47.7)	71 (43.3)	
Industry						
Trade/transportation	27 (22.3)	213 (25.5)		27 (25.2)	34 (20.7)	
Natural resources	2 (1.7)	47 (5.6)		4 (3.7)	3 (1.8)	
Construction	22 (18.2)	143 (17.1)		21 (19.6)	29 (17.7)	
Manufacturing	11 (9.1)	52 (6.2)		12 (11.2)	13 (7.9)	
Management	26 (21.5)	138 (16.5)		18 (16.8)	30 (18.3)	
Education/health	21 (17.4)	139 (16.7)		12 (11.2)	30 (18.3)	
Hospitality	12 (9.9)	102 (12.2)		13 (12.1)	25 (15.2)	
Physical demands at work			*			
Light	20 (16.5)	167 (20.0)		20 (18.7)	37 (22.6)	
Medium	35 (28.9)	267 (32.0)		36 (33.6)	52 (31.7)	
Heavy	29 (24.0)	206 (24.7)		22 (20.6)	38 (23.2)	
Very heavy	33 (27.3)	190 (22.8)		29 (27.1)	37 (22.6)	
Type of first medical visit			*			*
Primary care	61 (50.4)	385 (46.2)		53 (49.5)	61 (37.2)	
Occupational medicine	4 (3.3)	27 (3.2)		5 (4.7)	3 (1.8)	
Chiropractor	22 (18.2)	257 (30.8)		24 (22.4)	68 (41.5)	
Surgeon	7 (5.8)	17 (2.0)		2 (1.9)	1 (0.6)	
Emergency room/clinic	23 (19.0)	132 (15.8)		22 (20.6)	27 (16.5)	
Other	4 (3.3)	16 (1.9)		1 (0.9)	4 (2.4)	

[a] Roland-Morris disability questionnaire measures physical functioning relating to back pain.(66, 81)
[b] Any pain in the last week, scale ranges from 0-10.(80)
[c] SF-36 MH, Short Form-36 version 2 Mental Health scale.(77, 78)
[d] Mean of responses to 3 questions from the Pain Catastrophizing scale.(75)
[e] Mean of responses to two questions from the Fear-Avoidance Beliefs Questionnaire work scale.(76)

Among workers with mild/major sprains, those with early imaging had higher unadjusted RDQ scores (more impairment) at follow-up compared to workers whose treatment was consistent with guidelines (t-test, $p<0.01$) but did not differ significantly in terms of pain (Table 4.2). Among workers with radiculopathy, those with early imaging showed significantly higher pain and RDQ scores at one year (unadjusted t-test, $p<0.05$). For both categories of injury, workers with early imaging had worse unadjusted SF-36 scores than workers whose treatment was consistent with guidelines ($p<0.01$). After accounting for differences in baseline scores and covariates, however, results show that early MRI was not associated with significantly different scores for pain or SF-36 measures after one year (for both categories of injury) (Table 4.3). Among workers with mild/major sprains, follow-up RDQ scores were 1.12 points higher for those with early imaging, compared to those with imaging consistent with guidelines (95% CI:0.04-2.21, $p=0.043$). This was the only measure observed to differ significantly at follow-up in the multivariate analysis.

At one year, administrative records show that 14% of all workers were on disability. For workers with mild/major sprains, 31% of workers with early imaging were on disability, compared to 7% of those whose treatment was consistent with guidelines (χ^2 test, $p=0.01$) (Table 4.2). Among workers with radiculopathy, 40% of those with early imaging received disability, compared to 23% of those with imaging consistent with guidelines (χ^2 test, $p=0.01$). Similar patterns were observed for self-report of not working due to injury at one year (Table 4.2). Workers with early imaging had significantly more days on disability compared to those with imaging consistent with the guidelines for categories of injury; as expected, workers with radiculopathy had substantially more days on disability than workers with mild/major sprains (Table 4.2).

Table 4.2: Health and disability measures for workers with MRI before 6 weeks and those consistent with guidelines, stratified by injury severity groups (all measures were ascertained at 1-year follow-up interviews).

	Mild or major sprain/strain			Radiculopathy		
Health measures	**MRI within 6 weeks (N=121)**	**Consistent with guidelines (N=834)**	**Sig**	**MRI within 6 weeks (N=107)**	**Consistent with guidelines (N=164)**	**Sig**
Pain intensity the last week[a]	5.0 (2.7)	4.1 (5.3)		5.6 (2.6)	4.8 (2.8)	*
Roland-Morris disability score (RDQ)[b]	12.0 (7.1)	7.4 (6.8)	**	13.8 (6.8)	11.5 (7.4)	*
SF-36 Role Physical score[c]	38.3 (13.1)	46.0 (11.5)	**	35.8 (11.8)	41.2 (12.6)	**
SF-36 Physical Functioning score[d]	37.0 (12.6)	44.7 (12.1)	**	33.0 (11.7)	38.0 (12.6)	**
Disability measures						
On disability (receiving wage replacement benefits) [N(%)][g]	37 (30.6%)	56 (6.7%)	**	43 (40.2%)	37 (22.6%)	**
Not working due to injury [N(%)][h]	46 (38.0%)	91 (10.9%)	**	52 (48.6%)	48 (29.3%)	**
Total days on disability[e]	163.5 (144.6)	42.5 (86.6)	**	215.3 (137.5)	121.3 (142.6)	**

*p<0.05, **p<0.01.

Unless otherwise indicated, values reported are means and standard deviations (in parentheses). Significance tests compare early and late/no MRI groups using t-tests for health measures and total disability days and $\chi2$ tests for dichotomous disability measures.

[a] Any pain in the last week, scale ranges from 0-10.(80)

[b] Roland-Morris disability questionnaire measures physical functioning relating to back pain.(66, 81)

[c] Short Form-36 version 2 Role Physical scale, standardized (0-100).(77, 78)

[d] Short Form-36 version 2 Physical Functioning scale, standardized (0-100).(77, 78)

[g] Administrative report of no longer receiving TL at 365 days.

[h] Self-report of working within the last week, at follow-up.

[e] Total number of compensated days accrued within 35 days of claim receipt.

Table 4.3: Results of linear regression and survival analyses evaluating the effect of early MRI on health and disability outcomes at 1-year.

	Mild or major sprain/strain			Radiculopathy		
Health measures	**Coefficient[a]**	**95% CI**	**Sig**	**Coefficient[a]**	**95% CI**	**Sig**
Pain intensity the last week	0.11	-0.88, 1.08		0.06	-0.59, 0.71	
Roland-Morris disability score (RDQ)	1.12	0 .04, 2.21	*	0.07	-1.53, 1.67	
SF-36 Role Physical score	-1.94	-3.98, 0.10		-1.13	-4.00, 1.73	
SF-36 Physical Functioning score	-1.75	-3.77, 0.27		-1.47	-4.15, 1.21	
Disability measures	**RR[b]**	**95% CI**	**Sig**	**RR[b]**	**95% CI**	**Sig**
Receiving wage replacement benefits[c]	2.03	1.33, 3.11	**	1.31	0.84, 2.05	
Not working due to injury[d]	1.98	1.42, 2.76	**	1.21	0.85, 1.74	
	HR[b]	**95% CI**	**Sig**	**HR[b]**	**95% CI**	**Sig**
Ending work disability[f]	0.48	0.38, 0.60	**	0.57	0.40, 0.81	**

*p<0.05, **p<0.01
[a]Adjusted health outcome models control covariates listed in Table 4.1 and respective baseline health measure.
[b]Adjusted disability models control covariates listed in Table 4 1, and baseline pain and RDQ scores.
[c]Administrative report of no longer receiving TL at 365 days
[d]RR compares workers who received an early MRI to all other workers, adjusting for covariates listed above.
[e] Self-report of working within the last week, at follow-up.
[f] Work disability calculated using total TL accrued in 365 days from claim receipt. Hazard ratio describes rate of relative risk of ending disability comparing workers with early MRI to those with late/no MRI.

Multivariable results show that among workers with mild/major sprains, those who received early imaging were twice as likely to be receiving disability at one year, compared to workers with imaging consistent with guidelines (RR:2.03, 95% CI:1.33-3.11). Similar results were found for self-report of not working due to injury. Among workers with radiculopathy, early imaging was not associated with increased likelihood of disability (Table 4.3).

The Log Rank test for equality in survival functions and the Wilcoxon (Breslow) test both showed significant differences in ending disability compensation between those with early imaging and those with imaging consistent with guidelines, for both categories of injury (results in appendix). Multivariable Cox regression showed that those with early MRI experienced a slower rate of ending disability compensation, after adjusting for covariates (HR:0.48, 95% CI:0.38-0.60 among workers with mild/major sprains; HR:0.57, 95% CI:0.40-0.81 among workers with radiculopathy).

V. DISCUSSION

This analysis used a population-based, prospective design and large sample size of Washington State workers with LBP to evaluate the association between early imaging (MRI within six weeks of injury) and health and disability outcomes one year after injury. This study used administrative claims and interview data, which together provide a rich combination of independent and dependent variables for analyses. The availability of self-reported data is a substantial strength of the study, especially since the association between LBP, early imaging, and recovery emerges from a complex interaction between biological factors, pain tolerance, psychosocial effects such as catastrophizing and fear avoidance, work expectations, and social support.(115) In addition, occupational health research suggests that disability is associated with pain intensity, functional impairment, and psychosocial characteristics.(115-118)

Results show that early imaging was not associated with substantial improvements in pain or function, supporting previous research.(25, 56) For workers with mild/major sprains, early imaging was associated with slightly higher RDQ scores at follow-up, although this difference is not clinically meaningful.(119, 120) This research also supports studies that report an association between early imaging and prolonged work disability.(61, 121) We found that the effect of early imaging on disability varied by injury category. Among patients with mild/major sprains, early MRI was associated with higher risk of receiving disability compensation and not working at one year. The association between timing of MRI and long-term disability was not observed among workers with radiculopathy. All workers with early imaging, regardless of injury category, though, experienced a significantly slower rate of discontinuing work disability compared to those who did not receive early imaging.

The finding that early imaging impacts disability duration in the absence of substantial impacts on health may be the result of a combination of factors. Routine imaging may have little effect on treatment of LBP(58, 122), but patients with early imaging may experience adverse effects of imaging results, such as an avoidance of exercise or work if results are abnormal, even in the absence of greater pain.(122) Exaggerated perceived symptoms, altered coping response, or other adverse psychological effects of imaging(123, 124) may contribute to sensitivity to psychosocial job factors, like schedule flexibility, which are associated with higher rates of disability, independent of injury severity.(125)

This study does have several limitations. First, study subjects were limited to Washington State workers' compensation claimants with non-severe injuries that resulted in ≥4 days of compensated lost work time. While this restriction limits the generalizability of the results of this study to the working population with compensable, non-traumatic occupational injuries, these make up the majority of LBP injuries in the workers' compensation population.(30) Second, other than age, information on patient characteristics that may have indicated appropriate use of early MRI was not available for this study. However, these characteristics are uncommon in the general population and are less likely to be prevalent in a population of workers.(126) Finally, although we statistically adjusted for multiple individual-level variables, residual confounding may remain.

VI. CONCLUSIONS

The relationship between early lumbar imaging, healthcare utilization, time away from work, and health outcomes warrants further investigation to determine possible mechanisms of treatment and recovery. It may be possible that early diagnostic imaging triggers a "cascade of care" effect: subsequent procedures and other healthcare activities that, while not associated with better health outcomes at one year, may result in patients taking more time away from work. Those involved in the care and treatment of LBP, including reimbursement and funding decision-makers, will benefit from better understanding the consequences of early imaging.

Chapter 5. Conclusions

A. Summary and significance

Uncertainties arise from multiple directions in the assessment of acute LBP in the medical setting. Diagnostically, the manifestation of LBP as a symptom, rather than a disease, challenges physicians to classify patients into severity groups for subsequent treatment. Today's culture of escalating healthcare utilization, wherein "more is good," may pressure physicians to engage in more diagnostic procedures than are warranted for a patient with acute, nonspecific LBP. It is not surprising, then, when we observe high rates of MRI use within 4-6 weeks of LBP among patients without diagnostic red flags. Advanced imaging, however, lacks specificity in its diagnostic capabilities. Studies show that in asymptomatic patients, MRIs have observed abnormalities that are traditionally thought to attribute to LBP. In symptomatic patients, a positive finding could actually be a false positive finding – the LBP is not necessarily attributable to the MRIs findings.

Diagnostic imaging use is associated with increased utilization of healthcare, as illustrated in Chapter 3. Yet the patients who receive early imaging experience no better health outcomes than conventionally treated patients (Chapter 4). This dissertation research also found that early imaging is associated with slower rates of ending workers' compensation.

Following early imaging, patients proceed through the healthcare system. Those without particularly severe symptoms or neurological deficits may engage in a series of healthcare treatments and services that might have otherwise been deemed unneeded, if the patient had not received early imaging and proceeded through the healthcare system sooner. As shown in Chapter 3, workers with early imaging were more likely to receive injections, surgery, prescription drugs, and more office visits, after adjusting for injury severity and baseline factors such as demographics and psychosocial characteristics. Workers with early imaging also accrued higher costs. The study described in Chapter 4 shows that workers with early MRI do not appear to have better health outcomes and have slower rates of returning to work than other workers (Chapter 4). High rates of re-injury and/or chronic LBP that may result provide sobering evidence of our inability to effectively treat LBP.

Together with questionably effective treatments, inappropriate advanced imaging for nonspecific LBP initiates a series of events with repercussions and cost implications in the healthcare, employment, and disability sectors. This "cascade of care," the series of nonessential procedures and services resulting from inappropriate use or overuse of diagnostic tools, could be largely avoided, if reliable diagnoses and treatments for LBP were available. The health, cost, and disability implications described here highlight the importance of having and appropriately using reliable, specific diagnostic modalities for acute, nonspecific LBP, which could lead into a coordinated, capable system of evidence-based treatment.

B. Limitations

The three studies that make up this dissertation utilized data from the Washington Workers' Compensation Disability Risk Identification Study Cohort (D-RISC), a population-based study designed to identify risk factors for chronic disability among workers with acute back injury (details reported elsewhere).(65-67) The combined administrative claims and medical billing data used in D-RISC constitute a valuable source to answer questions such as those posed by this dissertation. The population-based design, large sample size, and detailed independent variables are strengths of this data.

However, use of this data does have several limitations. First, because the D-RISC data were limited to workers with ≥4 days compensable time loss for their injuries, results from these studies may not be generalized to workers with less severe or non-compensable LBP injuries. For instance, insurance status (including workers' compensation) may play a role in practice patterns and healthcare utilization.(127, 128) Second, baseline factors, such as physical demands at work, pain intensity, and RDQ scores, are self-reported. Workers who received early imaging with findings prior to interviews (17% of the cohort) may exhibit biases in their responses to interview questions, based on the results of their MRI exams. However, results from Chapter 2 suggest that this may not be the case. Third, these studies were observational in nature, and residual confounding cannot be entirely ruled out. The large number of individual-level, patient-reported covariates available for these studies helped address this concern. Finally, data from the D-RISC study were collected from 2002 to 2004. Since that time, changes may have occurred in the availability of imaging technologies and policies dictating use of imaging. In fact, in 2010, Washington State L&I implemented a policy requiring physicians treating workers' compensation claimants and seeking reimbursement to adhere to guidelines in the use of advanced imaging for certain types of injuries, including early MRI for acute low back pain.(108)

The advanced imaging policy implemented by L&I is illustrative of the complexity of healthcare utilization, which is the product of environmental factors as well as individual characteristics and health behaviors. As shown in the dissertation conceptual model (Figure 1.1), the external environment and healthcare system influence use of early imaging and health behaviors, independent of individual characteristics. The studies described in this dissertation are unique in their ability to control for a wide range of individual-level confounders, however, it was not possible to control for external, environmental factors that may influence care.

C. Implications

Evidence-based guidelines serve to inform clinicians about appropriate treatment protocol for patients with LBP, a common, yet complex, condition. Despite their value, however, guidelines are commonly overlooked and nonadherence is common.(39) Healthcare policies play an important role in ensuring safe, cost-effective, and appropriate use of advanced imaging technologies.

In 2009, the Washington State legislature passed House Bill ESHB 2105, which slated the Washington State Health Care Authority (HCA) with the responsibility to "implement the nationally accepted best practice guidelines or protocols applicable to advanced diagnostic imaging services, and the decision and support tools to implement the guidelines or protocols."(129) The HCA appointed a workgroup comprised of industry leaders, public payers, clinicians, and interest groups to "analyze and identify evidence-based best practice guidelines or protocols applicable to advanced diagnostic imaging services and any decision support tools available to implement the guidelines or protocols."(62) Using industry and public payer utilization data to guide priorities and nationally recognized standards to develop guidelines, the workgroup sought to identify principles to ensure cost-effectiveness, improvement of health and safety through reducing unnecessary radiation exposure, consistency across state agencies, use of high quality implementation tools, and reduction in provider administrative burden. In June 2010, consistent with findings and recommendations from the workgroup, the Washington State Department of Labor and Industries implemented a policy requiring physicians treating workers' compensation claimants and seeking reimbursement to adhere to guidelines in the management of certain types of injuries, including acute low back pain.(108)

Occupational LBP is a multi-factorial, complex condition. Early advanced imaging plays an important role in the diagnosis of serious underlying conditions that contribute to the LBP, but only in a fraction of the cases. Inappropriate use of early imaging can be avoided through adherence to evidence-based guidelines. Advanced imaging management policies, such as those implemented by L&I in 2010, are valuable tools for controlling the over- and misuse of early advanced imaging among LBP patients.

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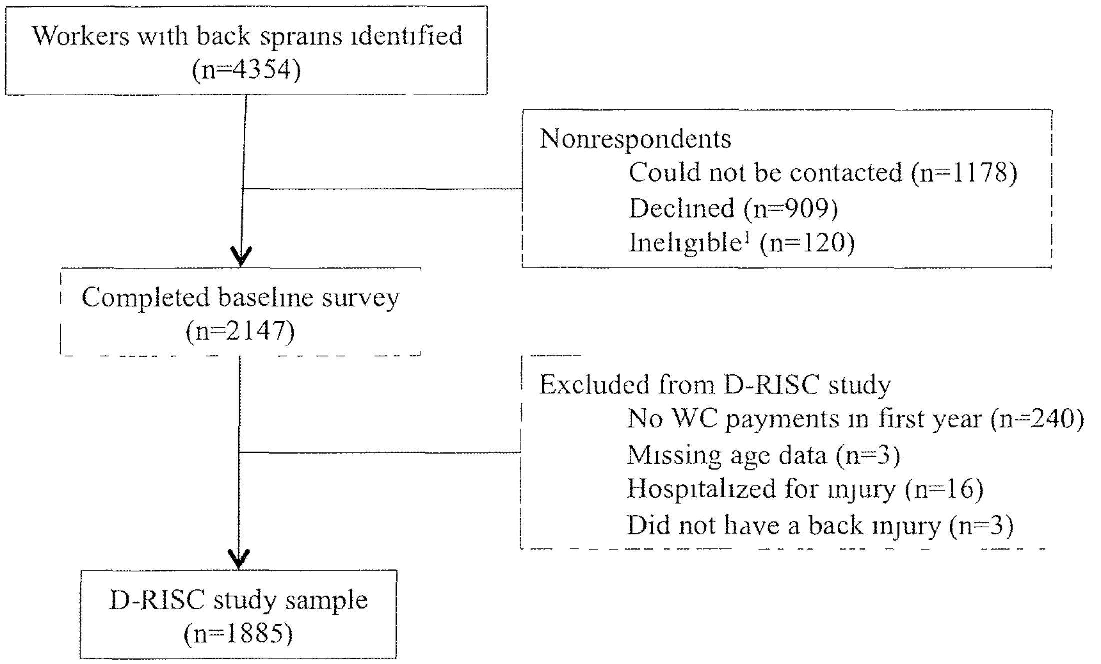
Appendix I. Recruitment and retention for D-RISC study

The following figure illustrates the recruitment of workers for the D-RISC study and final D-RISC sample size.[1]



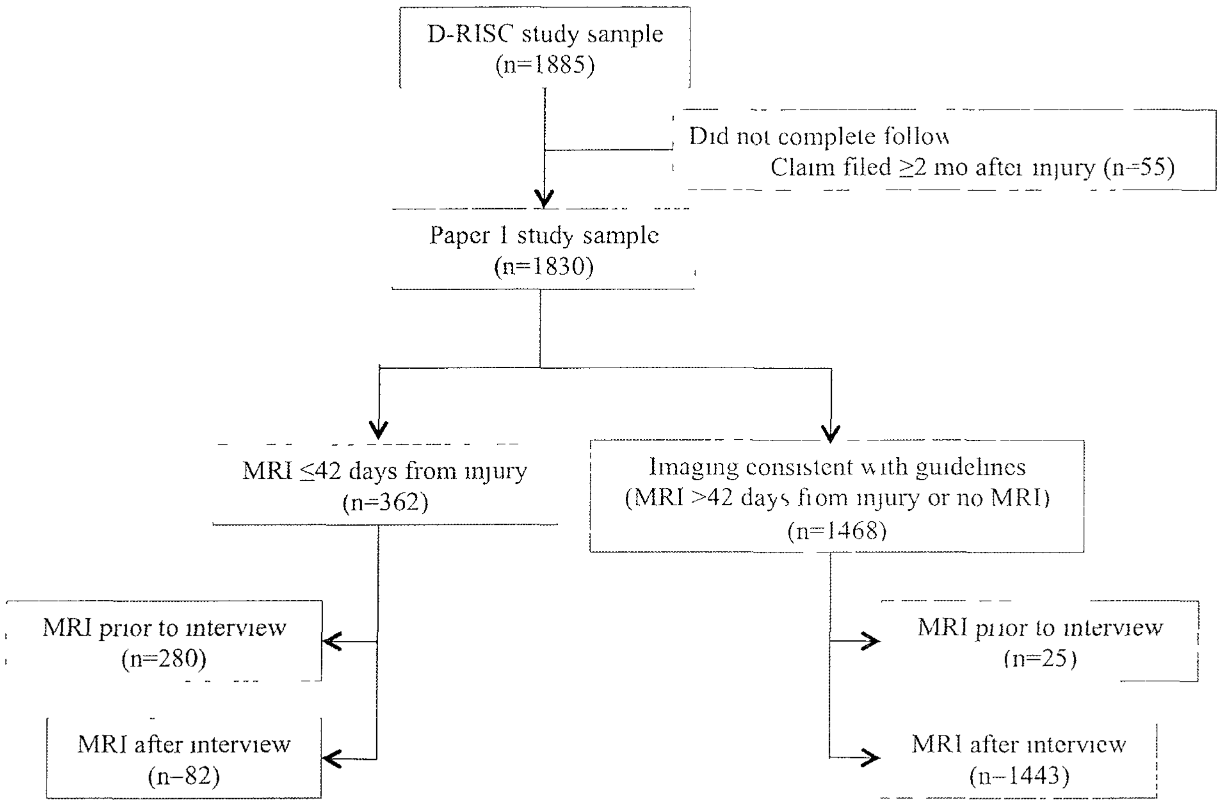
[1] e g. unable to complete interview in English or Spanish

Appendix II. Measurement matrix for Paper 1

Measure	Categories
Demographics	
Age (at injury, in years)	≤ 24, 25-34, 35-44, 45-54, ≥ 55
Sex	Female, male
Race	White, non-white
Ethnicity	Non-Hispanic, Hispanic
Education	Less than high school, high school diploma/GED, some college, college degree
Household income ($)	< 30000, 30-45000, 45-70000, >70000
Marital status	Married, living with partner, divorced, other
Health characteristics	
Body Mass Index (BMI)	Normal (<25), overweight (25-29), obese (30-34), very obese (>34)
Health in year before injury	Excellent, very good, good , fair or poor
SF36 Mental health score[a]	2 SD below population mean, 1-2 SD below population mean, 1 SD below population mean, at or above population mean
Catastrophizing[b] (0-4)	Low (<1), moderate (1-2 9), high (3-4)
Work fear-avoidance[c] (0-6)	Low (0-2 9), moderate (3-4 9), high (5-5 9), very high (6)
Clinical characteristics	
Type of first medical visit	Primary care, occupational medicine, chiropractor, surgeon, emergency room/clinic, other
Work characteristics	
Offered job accommodation for disability	Yes, no
1+ previous compensable back claims	Yes, no
Job satisfaction	Not at all, not too satisfied, somewhat satisfied, very satisfied
Industry	Natural resources, construction, manufacturing, trade/transportation, management, education/health, hospitality
Physical demands at work	Light, medium, heavy, very heavy
Injury characteristics	
Health status at time of interview	Excellent, very good, good , fair or poor
Pain intensity the last week[d]	Low/no pain (0-3), moderate (4-6), high (7-10)
Roland-Morris disability questionnaire score[e]	≤ 6, 7-12, 13-17, ≥ 18
Medical record documented injury severity rating	Mild sprain/strain and/or minor physical exam findings, major sprain/strain evidenced by substantial immobility, evidence of radiculopathy or reflexes absent

[a] SF-36v2 MH, Short Form-36 version 2 Mental Health scale [24,25]
[b] Mean of responses to 3 questions from the Pain Catastrophizing scale [22]
[c] Mean of responses to two questions from the Fear Avoidance Beliefs Questionnaire work scale [23]
[d] Any pain in the last week, scale ranges from 0 10 [27]
[e] Roland Morris disability questionnaire measures physical functioning relating to back pain [28,29]

Appendix III. Study population for Paper 1



Appendix IV. Measurement matrix for Paper 2

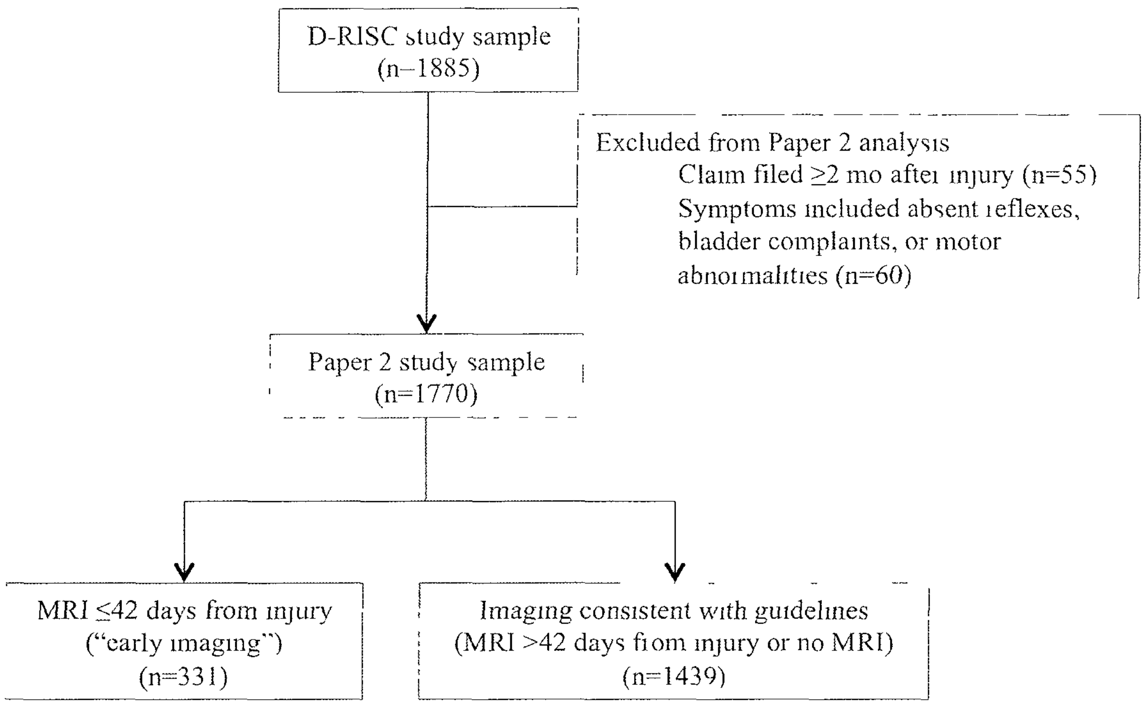
Measure	Categories
Baseline characteristics	
Age (at injury, in years)	≤ 24, 25-34, 35-44, 45-54, ≥ 55
Sex	Female, male
Race/ethnicity	Non-Hispanic white, non-Hispanic non-white, Hispanic non-white, Hispanic white
Education	Less than high school, high school diploma/GED, some college, college degree
Household income ($)	< 30000, 30-45000, 45-70000, >70000
Marital status	Married, living with partner, divorced, other
Body Mass Index (BMI)	Normal (<25), overweight (25-29), obese (30-34) very obese (>34)
Health in year before injury	Excellent, very good, good , fair or poor
Health status at time of interview	*Excellent, very good, good , fair or poor*
Roland-Morris disability questionnaire score[e]	Low (0-6), moderate (7-12), high (13-18), very high (19-24)
Pain intensity the last week[d]	Low/no pain (0-3), moderate (4-6), high (7-10)
Injury severity	Mild sprain/strain and/or minor physical exam findings, major sprain/strain evidenced by substantial immobility, evidence of radiculopathy or reflexes absent
SF36 Mental health score[a]	2 SD below population mean, 1-2 SD below population mean, 1 SD below population mean, at or above population mean
Catastrophizing[b] (0-4)	Low (<1), moderate (1-2 9), high (3-4)
Work fear-avoidance[c] (0-6)	Low (0-2 9), moderate (3-4 9), high (5-5 9), very high (6)
Offered job accommodation for disability	Yes, no
1+ previous compensable back claims	Yes, no
Job satisfaction	Not at all, not too satisfied, somewhat satisfied, very satisfied
Industry	Natural resources, construction, manufacturing, trade/transportation, management, education/health, hospitality
Physical demands at work	Light, medium, heavy, very heavy
Type of first medical visit	Primary care, occupational medicine, chiropractor, surgeon, emergency room/clinic, other

Measure	Description
Utilization measures (see also Appendix VI)	
MRI	Lumbar/lumbosacral MRI procedure reimbursed by L&I
CT	Lumbar/lumbosacral CT, procedure reimbursed by L&I
Radiograph	Lumbar/lumbosacral radiography, myelography, or discography procedure reimbursed by L&I
Injection	Epidural steroid injections, facet joint injections, sacroiliac joint injections, or other epidural or subarachnoid lumbar or sacral injections reimbursed by L&I
Surgery	Arthrodesis, posterior segment instrumentation, insertaion of intervertebral biomechanical device, laminectomy, laminotomy, or vertebral corpectomy of the lumbar region reimbursed by L&I
Prescription	Allowed L&I reimbursement for prescription medication
Chiropractic visit	Office/outpatient visit for chiropractic treatment or chiropractor provider, reimbursed by L&I See Appendix VI

Measure	Categories
PT/OT visit	Office/outpatient visit for PT/OT treatment or PT/OT provider, reimbursed by L&I See Appendix VI
Outpatient visit	*Office/outpatient visit for any procedures or treatment by a provider who is not chiropractor or PT/OT See Appendix VI*
Cost measures (see also Appendix VI)	
Outpatient services	All allowed costs for any procedures that took place during an outpatient visit
Inpatient services	All allowed costs for any service, treatment, or procedure that took place during hospitalization
Prescription drugs	All costs reimbursed by L&I for filled prescription medications
Disability compensation	Wage replacement compensation summed for 1 year post injury
Other WC costs[f]	Total costs for other WC expenses

[a] SF 36v2 MH Short Form 36 version 2 Mental Health scale [2,3]
[b] Mean of responses to 3 questions from the Pain Catastrophizing scale [4]
[c] *Mean of responses to two questions from the Fear Avoidance Beliefs Questionnaire work scale* [4]
[d] Any pain in the last week scale ranges from 0 10 [5]
[e] Roland Morris disability questionnaire measures physical functioning relating to back pain [6,7]
[f] Other WC costs were specific to occupational injuries and included costs included reimbursement for vocational (return to work) assistance employability assessments worker transportation medical devices and other costs not included in outpatient care costs

Appendix V. Study population for Paper 2



Appendix VI. Utilization and cost variable definitions (Paper 2)

The table below describes coding definitions for variables for Paper 2 analyses.

Table VI.1: Utilization variables.

Radiography (at least one charge meeting the criteria below, per worker, per day); Limited to lumbar only.	
Criteria	**Description**
CPT 72148	MRI, lumbar, without contrast material
CPT 72149	MRI, lumbar, with contrast material
CPT 72158	MRI, lumbar, without contrast material, followed by contrast material & further sequences
CPT 72131	CT,lumbar, without contrast material
CPT 72132	CT,lumbar, with contrast material
CPT 72133	CT,lumbar, without contrast material, followed by contrast material & further sections
CPT 72100	Radiologic examination of lumbosacral spine with 2-3 views
CPT 72110	Radiologic examination of lumbosacral spine with ≥4 views
CPT 72114	Radiologic examination of lumbosacral spine, complete, incl bending views
CPT 72120	Radiologic examination of lumbosacral spine, bending views only, ≥4 views
CPT 72265	Myelography, lumbosacral
CPT 72295	Diskography, lumbar
Lumbosacral injections	
Criteria	**Description**
CPT 62311	Injection, single, not including neurolytic substances, with or without contrast, of diagnostic or therapeutic substances, epidural or subarachnoid, lumbar/sacral (Caudal injection)
CPT 64483	Injection, anesthetic agent and/or steroid, transforaminal epidural, lumbar or sacral, single level (Transforaminal, lumbar, sacral)
CPT 64484	Injection, anesthetic agent and/or steroid, transforaminal epidural, lumbar or sacral, each additional level (Transforaminal, lumbar, sacral, each additional level)
CPT 64475	Injection, anesthetic agent and/or steroid, paravertebral facet joint or facet joint nerve, single level, lumbar or sacral (Facet lumbar or sacral, single level (foramen epidural))
CPT 64476	Injection, anesthetic agent and/or steroid, paravertebral facet joint or facet joint nerve, each additional level, lumbar or sacral (Facet lumbar or sacral, single level (foramen epidural, each additional level))
CPT 27096	Sacroiliac joint injection
CPT 62282	Injection/infusion of neurolytic substance (alcohol, phenol, iced saline solutions), with or without other therapeutic substance, subarachnoid, epidural, lumbar, sacral, caudal
CPT 62319	Injection, single, including catheter placement, continuous infusion or intermittent bolus, not including neurolytic substances, with or without contrast, of diagnostic or therapeutic substances, epidural or subarachnoid, lumbar/sacral
Surgery (at least one charge meeting the criteria below, per worker, per day); Limited to lumbar only.	
Criteria	**Description**

CPT 22102	Partial excision of a posterior vertebral component
CPT 22558	Arthrodesis, anterior/interbody, lumbar, single level (lumbar spine fusion)
CPT 22585	Arthrodesis, anterior/interbody, lumbar, each additional level
CPT 22612	Arthrodesis, posterior/posterolateral, lumbar, single level
CPT 22614	Arthrodesis, posterior/posterolateral, lumbar, each additional level
CPT 22630	Arthrodesis, posterior interbody w/laminectomy/diskectomy, lumbar, single interspace
CPT 22632	Arthrodesis, posterior interbody w/laminectomy/diskectomy, lumbar, each additional interspace
CPT 22842	Posterior segment instrumentation, 3–6 vertebral segments (code is only used in conjunction with other surgical codes)
CPT 22843	Posterior segment instrumentation, 7-12 vertebral segments (code is only used in conjunction with other surgical codes)
CPT 22844	Posterior segment instrumentation, 13+ vertebral segments (code is only used in conjunction with other surgical codes)
CPT 22845	Anterior instrumentation, 2–3 vertebral segments (code is only used in conjunction with other surgical codes)
CPT 22846	Anterior instrumentation, 4-7 vertebral segments (code is only used in conjunction with other surgical codes)
CPT 22847	Anterior instrumentation, 8+ vertebral segments (code is only used in conjunction with other surgical codes)
CPT 22851	Intervertebral biomechanical device(s) to vertebral defect/interspace (code is only used in conjunction with other surgical codes)
CPT 63005	Laminectomy without facetectomy/foraminotomy/diskectomy, 1/2 segments, lumbar, (removal of spinal lamina, Lumbar stenosis surgery)
CPT 63015	Laminectomy with exploration, without facetectomy, foraminotomy, or diskectomy, lumbar
CPT 63012	Laminectomy with removal of abnormal facets and/or pars inter-articularis with decompression of cauda equina & nerve roots for spondylolisthesis, lumbar
CPT 63017	Laminectomy without facetectomy/foraminotomy/diskectomy, 2 segments, lumbar, (removal of spinal lamina, Lumbar stenosis surgery)
CPT 63030	Laminotomy w/partial facetectomy/foraminotomy/herniated diskectomy, 1 interspace, lumbar, (low back disk surgery)
CPT 63035	Laminotomy (hemilaminectomy) with decompression of nerve roots, including partial facetectomy, foraminotomy, and/or excision of herniated intervetebral disk, lumbar, each additional interspace
CPT 63042	Laminotomy w/partial facetectomy/foraminotomy/herniated diskectomy, re-exploration, lumbar, (low back disk surgery)
CPT 63044	Laminotomy (hemilaminectomy) with decompression of nerve roots, including partial facetectomy, foraminotomy, and/or excision of herniated intervetebral disk, lumbar, each additional interspace (Reexploration)
CPT 63047	Laminectomy, facetectomy and foraminotomy, 1 segment, lumbar, (removal of spinal lamina, Lumbar stenosis surgery)
CPT 63048	Laminotomy, facetectomy, and foraminotomy, each additional vertebral segment, lumbar
CPT 63087	Vetebral corpectomy (vertebral body resection), combined thoracolumbar approach, lower thoracic or lumbar, single segment
CPT 63088	Vetebral corpectomy (vertebral body resection), combined thoracolumbar approach, lower thoracic or lumbar, each additional segment
CPT 63090	Vetebral corpectomy (vertebral body resection), transperitoneal or retroperitoneal approach, lower thoracic, lumbar, or sacral, single segment
CPT 63091	Vetebral corpectomy (vertebral body resection), transperitoneal or retroperitoneal approach, lower thoracic, lumbar, or sacral, each additional segment
CPT 63102	Vetebral corpectomy (vertebral body resection), lateral extracavitary approach, lumbar, single segment
CPT 63103	Vetebral corpectomy (vertebral body resection), lateral extracavitary approach, lumbar, each additional segment
CPT 63200	Laminectomy, with release of tethered spinal cord, lumbar
CPT 63267	Laminectomy for excision or evaluation of intraspinal lesion other than neoplasm, extradural, lumbar
CPT 63272	Laminectomy for excision or evaluation of intraspinal lesion other than neoplasm, intradural, lumbar
CPT 63277	Laminectomy for biopsy/excision of intraspinal neoplasm, extradural, lumbar (TUMOR)

CPT 63282	Laminectomy for biopsy/excision of intraspinal neoplasm, intradural, extramedullary, lumbar (TUMOR)
CPT 63287	Laminectomy for biopsy/excision of intraspinal neoplasm, intradural, intramedullary, lumbar (TUMOR)
CPT 63303	Vetebral corpectomy (vertebral body resection), partial or complete, for excision of intraspinal lesion, single segment, extradural, lumbar or sacral by transperitoneal or retropeironeal approach
CPT 63307	Vetebral corpectomy (vertebral body resection), partial or complete, for excision of intraspinal lesion, single segment, intradural, lumbar or sacral by transperitoneal or retropeironeal approach
CPT 62270	Spinal puncture, lumbar, diagnostic
CPT 62272	Spinal puncture, therapeutic, for drainage of cerebrospinal fluid

Chiropractic therapy visits (at least one charge meeting the criteria below, per worker, per day)

Criteria			Description
CPT 99201-99380	&	L&I provider type: Chiropractor (30), Clinic-chiropractic (53)	Office visit with a provider that is a chiropractor (defined by L&I provider type)
CPT 99201-99380	&	L&I provider specialty Chiropractor (98), Chiropractor consultant (96)	Office visit with a provider that is a chiropractor (defined by L&I provider type)
CPT 97110-97112	&	L&I provider type Chiropractor (30), Clinic-chiropractic (53)	Therapeutic procedure with a provider that is a chiropractor (defined by L&I provider type)
CPT 97110-97112	&	L&I provider specialty Chiropractor (98), Chiropractor consultant (96)	Therapeutic procedure with a provider that has a chiropractic specialty (defined by L&I provider specialty)
CPT 98940-98942			Chiropractic manipulative treatment
CPT 98925-98929			Osteopathic manipulative treatment
L&I type of service Chiropractic ("C")			Any procedure/visit with L&I type of service as "Chiropractic"
L&I local code 2050A			Chiropractor visit (L&I local code, level 1 chiropractic care)
L&I local code 2051A			Chiropractor visit (L&I local code, level 2 chiropractic care visit)
L&I local code 2052A			Chiropractor visit (L&I local code, level 3 chiropractic care visit)

Physical/Occupational Therapy (PT/OT) visits (at least one charge meeting the criteria below, per worker, per day)

Criteria			Description
CPT 99201-99380	&	L&I provider type Physical therapist (34), Clinic/physical therapy (52), Occupational therapist (55)	Office visit with a provider that is a PT or OT (defined by L&I provider type)
CPT 99201-99380	&	L&I provider specialty. Physical therapist (65)	Office visit with a provider that is a PT oi OT (defined by L&I specialty type)
CPT 97110-97112	&	L&I provider type Physical therapist (34), Clinic/physical therapy (52), Occupational therapist (55)	Therapeutic procedure with a provider that is a PT or OT (defined by L&I provider type)

CPT 97110-97112	&	L&I provider specialty Physical therapist (65)	Therapeutic procedure with a provider that has a PT or OT specialty (defined by L&I provider specialty)
CPT 97001			Physical therapy evaluation
CPT 97002			Physical therapy re-evaluation
CPT 97003			Occupational therapy evaluation
CPT 97004			Occupational therapy re-evaluation
L&I type of service		Physical therapist(P)	Any procedure/visit with L&I type of service as physical therapist

Office visit (at least one charge meeting the criteria below, per worker, per day)

Criteria			**Description**
CPT 99201-99380	&	L&I provider type not Chiropractor (30), Clinic-chiropractic (53), Physical therapist (34), Clinic/physical therapy (52), Occupational therapist (55), Durable medical equipment (39), Personal transport (42), Lab facility (43), public transportation (45), Ambulance (51), Training services (76), or VOC (vocational training) (68)	Provider type may include Physician (20), Physician assistant (21), Osteopathic physician (22), Radiology (25), Pharmacy (26), Psychologist (31), Podiatric physician (32), Clinic (36), Prosthetist/orthotist (38), Nurse (40), Home health agency (44), Nursing home (46), Massage therapy (54), Pain clinic (70), IME exam group (78), Ambulatory surgery center (86), Naturopath (92), Misc (97)
CPT 99201-99380	&	L&I provider specialty not Chiropractor (98), Chiropractor consultant (96), Physical therapist (65), Medical transportation (59), Medical supply (51), Vocational intern (75), Vocational counselor (73), Lodging (90), Taxi (93), or Airline (95), Interpreter (I1 & I2), Investigative services (13)	Specialty may include General practice (1), General surgery (2), Allergy (3), Otology-laryongology (4), Anesthesiology (5), Cardiovascular (6), Dermatology (7), Family practice (8), Gastroenterology (10), Neurology (13), Neurological surgery (14), OBGYN (16), Orthopedic surgery (20), Hand surgery (21), Pathology (22), Vascular surgery (23), Physical medicine/rehab (25), Pulmonary (29), Radioogy (30), Nuclear medicine (32), Thoracic surgery (33), urology (34), Psychiatry (36), Pediatrics (40), Internal medicine (41), ER MD (47), Podiatry (48), Psychology (62), Infusion therapy (66), Certified hand therapist (67), Laboratory diagnostic (69), Clinic (70), Sports medicine (71), Rheumatology (72), Occupational medicine (76), Dolorology (77), Nephrology (85), Medical (97), IME firms (A5, A6), Skilled nursing facility (H3), Home health care (H6), Nurse (N1, N2, N3)
CPT 99201-99380	&	L&I type of service not Physical therapist ("P"), Chiropractic ("C"), or Vocational ("V")	Type of service may include Drugless therapy ("D"), Nurse practitioner ("N"), Other CPT services ("3"), or Medical ancillary services ("9")

Table VI.1: Cost variables.

Inpatient costs (sum of all costs (per worker) that meet the criteria below)	
	Allowed costs in hospital file, includes bills for any inpatient care or services
	Costs for outpatient care that took place during the dates of an inpatient visit were totaled as inpatient costs
Prescription drug costs (sum of all costs (per worker) that meet the criteria below)	
	Any allowed costs in pharmacy file, includes only filled prescriptions reimbursed by L&I
Time Loss compensation	
	Total time loss accrued in the first 365 after injury (uses data from file sent by Rae in April 2011 updateddatafromjerry42011 dta)
Other WC costs (sum of all costs (per worker) that meet the criteria below)	
	Other professional/ancillary costs, Includes miscellaneous WC costs, like worker transportation, filling out of special forms for accident report, med devices, etc (all HCPCS codes and L&I local codes that were not included in medical costs) Defined as any charge that is not covered by inpatient, outpatient, or prescription drug costs that are associated with occupational rehabilitation aspect of claim
Outpatient care (sum of all costs (per worker) that meet the criteria below)	
Criteria	**Description**
CPT 00000-99999	CPT code identifying any medical/healthcare service
L&I local codes 2010M, 2011M, 2014M, 2015M	Pain clinic evaluation, treatment, or follow-up services
L&I local codes 2050A-2052A	Chiropractic care visit
L&I local codes 8880H-8890H	Nursing facility rehab or care
L&I local codes 8893H-8895H	L&I Residential facility care
L&I local code 8901H	Attendant svcs
L&I local code 8902H	Nursing home or residential care (group home, boarding home)
L&I local codes 8950H-8952H	Brain injury evaluation and rehabilitation
L&I local codes 0440A & 0441A	Weight loss programs
HCPCS code B	Enteral and parenteral therapy
HCPCS code C	Temporary codes for use with outpatients
HCPCS code D	Dental services
HCPCS code G	Procedures/professional services, temp
HCPCS code H	Alcohol/drug tx services
HCPCS code J	Drugs administered
HCPCS code L	Orthotic procedures, prosthetic proc
HCPCS code M	Medical services
HCPCS code P	Pathology/lab services
HCPCS code R	Dx radiology codes
HCPCS code V	Vision services/hearing

Appendix VII. Model specification for 2-part cost model analysis, Paper 2

In order to achieve both consistency and efficiency, Box-Cox and modified Park-tests are used to determine the best choice of GLM link and family estimator.[8,9]

Results of Box-Cox test for cost models

Model	λ	SE	p-values $\lambda=-1$	$\lambda=0$	$\lambda=1$	GLM link chosen
Medical costs	0.140	0.017	0.000	0.000	0.000	ln(y)
Inpatient costs	0.077	0.040	0.000	0.052	0.000	ln(y)
Pharmacy costs	0.071	0.029	0.000	0.015	0.000	ln(y)
Other WC costs	0.060	0.016	0.000	0.000	0.000	ln(y)
Time-loss compensation	0.088	0.006	0.000	0.000	0.000	ln(y)

KEY
- If $\lambda=-1$ inverse $(1/y) = X\beta + \varepsilon$
- If $\lambda=0$ ln(y) $\ln(y)=X\beta+\varepsilon$
- If $\lambda=.5$ squareroot $\text{sqrt}(y)=X\beta+\varepsilon$
- If $\lambda=1$ linear $y=X\beta+\varepsilon$

Results of modified Park test for cost models

Model	θ-hat	SE	p-values $\theta=0$	$\theta=1$	$\theta=2$	$\theta=3$	GLM family chosen
Medical costs	1.861	0.131	0.000	0.000	0.288	0.000	Poisson (or Gamma)
Inpatient costs	1.668	0.366	0.000	0.069	0.365	0.000	Gamma
Pharmacy costs	2.251	0.248	0.000	0.000	0.312	0.003	Gamma
Other WC costs	1.484	0.115	0.000	0.001	0.000	0.000	Poisson (or Gamma)
Time-loss compensation	1.650	0.062	0.000	0.000	0.000	0.000	Poisson (or Gamma)

This test is performed by running OLS on the logarithm of the squared residuals from the raw scale on a constant and the logarithm of the raw-scale predicted values

$\ln(y - \hat{y})^2 = \theta_0 + \theta_1 \ln(\hat{y}) + u$, where $\hat{y} = \exp(x\beta)$

The choice of which GLM specification to choose then depends on the estimate of θ, Manning and Mullahy suggest choosing the NLS model if $\theta = 0$, the Poisson class model if $\theta = 1$, the gamma model if $\theta = 2$, or the inverse Gaussian model if $\theta = 3$ [9]

Appendix VIII. Measurement matrix for Paper 3

Measure	Categories
Demographic, work, clinical, and health history characteristics of study subjects	
Age (at injury, in years)	≤ 24, 25-34, 35-44, 45-54, ≥ 55
Sex	Female, male
Race/ethnicity	White non-Hispanic white, Non-white non-Hispanic, Hispanic
Education	Less than high school, high school diploma/GED, some college, college degree
Household income ($)	< 30000, 30-45000, 45-70000, >70000
Marital status	Married, living with partner, divorced, other
Body Mass Index (BMI)	Normal (<25), overweight (25-29), obese (30-34), very obese (>34)
Health in year before injury	Excellent, very good, good, fair or poor
Health status at time of interview	Excellent, very good, good, fair or poor
Roland-Morris disability questionnaire score[e]	Low (0-6), moderate (7-12), high (13-18), very high (19-24)
Pain intensity the last week[d]	Low/no pain (0-3), moderate (4-6), high (7-10)
Injury severity	Mild sprain/strain and/or minor physical exam findings, major sprain/strain evidenced by substantial immobility, evidence of radiculopathy or reflexes absent
SF36 Role Physical score[a]	0-100 scale, standardized to categories based on U S population norms wherein mean=50 and SD=10 Categories 2 SD below population mean, 1-2 SD below population mean, 1 SD below population mean, at or above population mean
SF36 Physical Functioning score[a]	0-100 scale, standardized to categories based on U S population norms wherein mean=50 and SD=10 Categories 2 SD below population mean, 1-2 SD below population mean, 1 SD below population mean, at or above population mean
SF36 Mental health score[a]	0-100 scale, standardized to categories based on U S population norms wherein mean=50 and SD=10 Categories 2 SD below population mean, 1-2 SD below population mean, 1 SD below population mean, at or above population mean
Catastrophizing[b] (0-4)	Low (<1), moderate (1-2 9), high (3-4)
Work fear-avoidance[c] (0-6)	Low (0-2 9), moderate (3-4 9), high (5-5 9), very high (6)
Offered job accommodation for disability	Yes, no
1+ previous compensable back claims	Yes, no
Job satisfaction	Not at all, not too satisfied, somewhat satisfied, very satisfied
Industry	Natural resources, construction, manufacturing, trade/transportation, management, education/health, hospitality
Physical demands at work	Light, medium, heavy, very heavy
Type of first medical visit	Primary care, occupational medicine, chiropractor, surgeon, emergency room/clinic, other
Health measures	
Pain intensity the last week[d]	0-10 scale

Roland-Morris disability score (RDQ)[e]	0-24 scale
SF36v2 Role Physical score[a]	0-100 scale
SF36v2 Physical Functioning score[a]	0-100 scale
Disability measures	
On disability (receiving wage replacement benefits 1 year after injury)	Yes, no
Not working due to injury	Yes, no
Total days on disability	Continuous measure (days)

[a] SF-36v2 MH, Short Form-36 version 2 Mental Health scale [2,3]
[b] Mean of responses to 3 questions from the Pain Catastrophizing scale [4]
[c] Mean of responses to two questions from the Fear-Avoidance Beliefs Questionnaire work scale [4]
[d] Any pain in the last week, scale ranges from 0-10 [5]
[e] Roland-Morris disability questionnaire measures physical functioning relating to back pain [6,7]
[f] Other WC costs were specific to occupational injuries and included costs included reimbursement for vocational (return-to-work) assistance, employability assessments, worker transportation, medical devices, and other costs not included in outpatient care costs

Appendix IX: Characteristics of non-respondent workers at follow-up, Paper 3

Comparison of workers who completed follow-up interviews and workers who did not.

	Non-respondents at follow-up (N=566) N (%)	Completed follow-up (N=1319) N (%)	Sig
Early imaging			
Early imaging (MRI ≤6 weeks from symptom onset)	107 (18.9)	256 (19 4)	
Consistent with guidelines (MRI >6 weeks from symptom onset)	459 (81.1)	1063 (80 6)	
Age (at injury)			**
Under 24 yrs	85 (15.0)	113 (8 6)	
25-34 yrs	170 (30 0)	307 (23.3)	
35-44 yrs	169 (29 9)	410 (31.1)	
45-54 yrs	94 (16.6)	348 (26 4)	
Over 55 yrs	48 (8.5)	141 (10 7)	
Sex			
Female	163 (28.8)	440 (33 4)	
Male	403 (71.2)	879 (66 6)	
Race/ethnicity			**
Non-Hispanic, white	362 (64.0)	956 (72 5)	
Non-Hispanic, non-white	76 (13.4)	174 (13 2)	
Hispanic	99 (17.5)	161 (12.2)	
Education			**
Less than high school	106 (18.7)	145 (11 0)	
High school diploma/GED	210 (37.1)	436 (33 1)	
Some college	219 (38.7)	606 (45 9)	
College degree	30 (5 3)	132 (10.0)	
Household income ($)			**
< 30,000	270 (47.7)	481 (36 5)	
30-45,000	140 (24.7)	334 (25 3)	
45-70,000	88 (15.5)	330 (25 0)	
>70,000	40 (7 1)	138 (10.5)	
Marital status			**
Married	236 (41 7)	719 (54.5)	
Living with partner	86 (15.2)	178 (13.5)	
Divorced	117 (20.7)	253 (19 2)	
Other	125 (22 1)	168 (12.7)	
Body Mass Index (BMI)			
Normal <25	177 (31.3)	384 (29.1)	
Overweight 25-29	222 (39.2)	508 (38.5)	
Obese 30-34	106 (18 7)	278 (21 1)	
Very obese >34	46 (8 1)	121 (9.2)	
Health in year before injury			
Excellent	132 (23 3)	299 (22.7)	
Very good	188 (33.2)	496 (37 6)	

	Non-respondents at follow-up (N=566) N (%)	Completed follow-up (N=1319) N (%)	Sig
Good	170 (30 0)	399 (30 3)	
Fair/Poor	75 (13 3)	123 (9 3)	
Health status at baseline interview			*
Excellent	115 (20 3)	252 (19 1)	
Very good	175 (30 9)	496 (37 6)	
Good	189 (33 4)	420 (31 8)	
Fair/poor	86 (15 2)	149 (11 3)	
Roland-Morris score[a] (0-24)			
Low (0-6)	121 (21 4)	311 (23 6)	
Moderate (7-12)	106 (18 7)	285 (21 6)	
High (13-18)	173 (30 6)	376 (28 5)	
Very high (19-24)	166 (29 3)	347 (26 3)	
Pain intensity[b] (0-10)			*
Low/no pain (0-3)	120 (21 2)	338 (25 6)	
Mild pain (4-6)	223 (39 4)	489 (37 1)	
Moderate/high pain (7-10)	220 (38 9)	492 (37 3)	
SF36v2 Role Physical score[c]			*
2 SD below population mean	183 (32 3)	480 (36 4)	
1-2 SD below population mean	163 (28 8)	312 (23 7)	
1 SD below population mean	97 (17 1)	242 (18 3)	
At or above population mean	120 (21 2)	285 (21 6)	
SF36v2 Physical Functioning score[c]			
2 SD below population mean	187 (33 0)	416 (31 5)	
1-2 SD below population mean	141 (24 9)	292 (22 1)	
1 SD below population mean	106 (18 7)	289 (21 9)	
At or above population mean	132 (23 3)	322 (24 4)	
SF36 Mental health score[c]			
2 SD below population mean	89 (15 7)	193 (14 6)	
1-2 SD below population mean	134 (23 7)	276 (20 9)	
1 SD below population mean	144 (25 4)	329 (24 9)	
At or above population mean	197 (34 8)	521 (39 5)	
Catastrophizing[d] **(0-4)**			
Low (<1)	116 (20 5)	313 (23 7)	
Moderate (1-2 9)	305 (53 9)	706 (53 5)	
High (3-4)	145 (25 6)	300 (22 7)	
Work fear-avoidance[e] **(0-6)**			
Low (0-2 9)	122 (21 6)	254 (19 3)	
Moderate (3-4 9)	179 (31 6)	427 (32 4)	
High (5-5 9)	178 (31 4)	384 (29 1)	
Very high (6)	87 (15 4)	254 (19 3)	
Offered job accommodation for disability			
Yes	239 (42 2)	616 (46 7)	
No	320 (56 5)	687 (52 1)	
1+ previous compensable back claims			

	Non-respondents at follow-up (N=566) N (%)	Completed follow-up (N=1319) N (%)	Sig
Yes	107 (18 9)	266 (20.2)	
No	454 (80.2)	1048 (79.5)	
Job satisfaction			
Not at all	41 (7.2)	68 (5 2)	
Not too satisfied	55 (9.7)	108 (8.2)	
Somewhat satisfied	225 (39 8)	563 (42 7)	
Very satisfied	243 (42.9)	577 (43.7)	
Industry			*
Trade/transportation	135 (23.9)	328 (24.9)	
Natural resources	35 (6 2)	59 (4.5)	
Construction	105 (18 6)	231 (17.5)	
Manufacturing	55 (9 7)	95 (7 2)	
Management	77 (13.6)	231 (17 5)	
Education/health	73 (12.9)	211 (16 0)	
Hospitality	86 (15.2)	164 (12 4)	
Physical demands at work			
Light	112 (19.8)	272 (20.6)	
Medium	179 (31.6)	416 (31.5)	
Heavy	135 (23.9)	312 (23.7)	
Very heavy	138 (24.4)	311 (23.6)	
Type of first medical visit			
Primary care	237 (41.9)	604 (45.8)	
Occupational medicine	20 (3 5)	43 (3.3)	
Chiropractor	178 (31.4)	392 (29.7)	
Surgeon	9 (1 6)	33 (2.5)	
Emergency room/clinic	116 (20 5)	219 (16.6)	
Other	6 (1 1)	28 (2.1)	
Injury severity			
Mild sprain/strain and/or minor physical exam findings	314 (55.5)	715 (54.2)	
Major sprain/strain evidenced by substantial immobility	119 (21.0)	262 (19 9)	
Evidence of radiculopathy	113 (20.0)	288 (21.8)	
Reflexes absent, bladder complaints	17 (3 0)	47 (3.6)	
Disability measures (administrative data only)			
On disability (receiving wage replacement benefits) [N(%)][f]	63 (11.1)	202 (15.3)	*
Total days on disability [mean(SD)][g]	79 (119)	86 (127)	

*p<0 05, **p<0 01

Values reported are counts and percentages (in parentheses), unless otherwise indicated Significance tests compare workers who did and did not complete follow-up interviews using χ^2 tests (or t-tests for continuous measures)

[a] Roland-Morris disability questionnaire measures physical functioning relating to back pain [1 2]

[b] Any pain in the last week, scale ranges from 0-10 [3]

[c] SF-36v2 MH, Short Form-36 version 2 Mental Health scale [4 5]

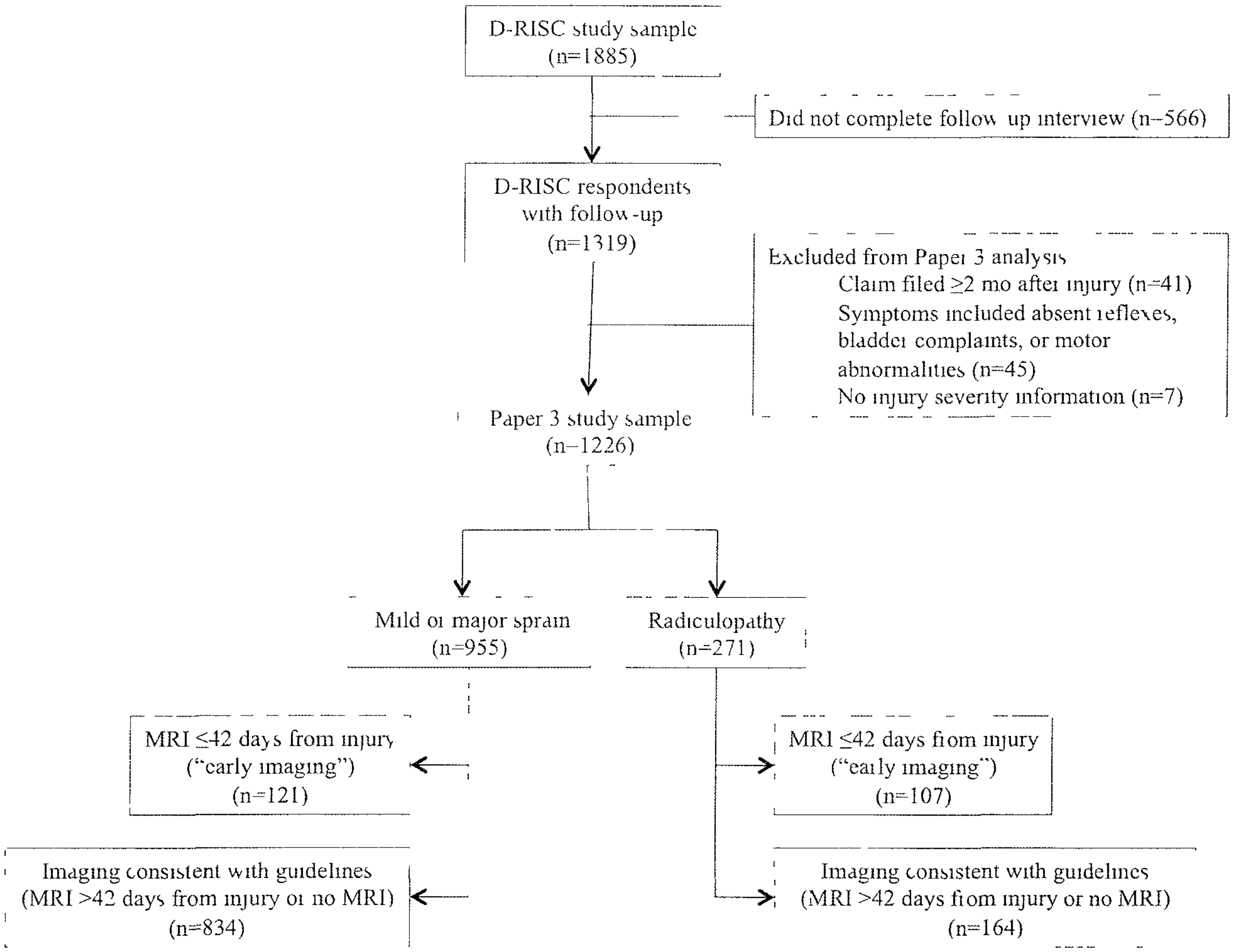
[d] Mean of responses to 3 questions from the Pain Catastrophizing scale [6]

[e] Mean of responses to two questions from the Fear-Avoidance Beliefs Questionnaire work scale [7]

[d] Administrative report of no longer receiving TL at 365 days

[e] Total number of compensated days accrued within 365 days of claim receipt

Appendix X. Study population for Paper 3



Appendix XI. Non-parametric survival analysis results, Paper 3

The Log Rank and Wılcoxson (Breslow) tests compare two survıval curves across multıple tıme poınts to answer the questıon—"ıs overall survıval dıfferent between the gıoups?" They do not provıde an estımate of effect (e g a hazard ratıo) or a confidence ınterval, nor do they adjust for confoundıng

Ho S(t) = S(t) Equalıty ın tıme to endıng dısabılıty compensatıon
HA S(t) =/S(t) Tıme to endıng dısabılıty compensatıon not equal between groups

Log-rank test for equality of survivor functions

	Mild or major sprain/strain		Radiculopathy	
	Events observed	**Events expected**	**Events observed**	**Events expected**
Early ımagıng (MRI ≤6 weeks from symptom onset)	95	219	80	114
Consıstent wıth guıdelınes (MRI >6 weeks from symptom onset)	804	680	142	108
Total	899	899	222	222
χ^2 **Statistic** (1 df)		102 55		21 00
P-value		<0 0001		<0 0001

Wilcoxon (Breslow) test for equality of survivor functions

	Mild or major sprain/strain			Radiculopathy		
	Events observed	**Events expected**	**Sum of ranks**	**Events observed**	**Events expected**	**Sum of ranks**
Early ımagıng (MRI ≤6 weeks from symptom onset)	95	219 02	-63817	80	113 78	-7398
Consıstent wıth guıdelınes (MRI >6 weeks from symptom onset)	804	679 98	63817	142	108 22	7398
Total	899	899 00	0	222	22 00	0
χ^2 **Statistic** (1 df)			106 44			34 25
P-value			<0 0001			<0 0001

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Vita

Janessa M Giaves was born in Missoula, Montana She earned a Bachelors of Arts in Environmental Biology (*Cum laude*) from Barnard College, Columbia University in New York, New York She has lived, worked, and studied in the U S , Germany, Greece, Kenya, and the Republic of the Fiji Islands, were she served as a Peace Corps Volunteer with her husband She earned a Masters of Public Health in Environmental and Occupational Health from the University of Washington in 2008 In 2011, she earned a Doctor of Philosophy at the University of Washington in Health Services Research