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UMI
A Case-Control Study of Biomechanical and Psychosocial Risk Factors for Low-Back Pain Reported in an Occupational Setting

by

Michael Steven Kerr

A thesis submitted in conformity with the requirements for the degree of Doctor of Philosophy
Graduate Department of Community Health
University of Toronto

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Title: A Case-Control Study of Biomechanical and Psychosocial Risk Factors for Low-back Pain Reported in an Occupational Setting

Author: Michael Steven Kerr

Degree: Doctor of Philosophy (Epidemiology)

Year: 1998

Department: Graduate Department of Community Health

University: University of Toronto

Abstract

Objectives: The main aim of this study was to identify risk factors for occupational low-back pain (LBP), including: workplace biomechanical factors; psychosocial work environment variables; and individual worker characteristics. A unique feature of this study was the combination of extensive workplace biomechanical assessments with detailed psychosocial questionnaire assessments.

Design and Methods: 137 cases were drawn from the study base of all hourly-paid employees at a large automobile manufacturing complex. The cases, defined as workers with acute “sprain-strain” LBP newly reported to one of the onsite occupational health clinics, were compared with 179 unmatched controls, chosen at random from the study base as the cases accrued. Any worker with a LBP report at the worksite in the previous 90 days was ineligible. An interview-assisted questionnaire assessed individual, clinical and psychosocial variables. Workplace
biomechanical factors were assessed using a variety of direct measures, including video-taped posture analysis and biomechanical model estimates of forces in the lumbar spine. Risk factors were examined using multiple logistic regression, with the odds ratio (OR) estimates for continuous covariates scaled to the unit difference between the 75th and 25th percentiles of the random control distribution. Additional analyses examined the effect of unreported LBP, the validity of using proxy biomechanical data, the main psychosocial instrument used, and agreement between the cases and a group of job-matched controls on the key study variables.

Results: The measured physical demands of work associated with reported LBP at the study site were: i) peak shear force (OR=1.9, 95% CI 1.2-3.2); ii) peak hand force (OR=1.8, 1.2-2.9); and iii) integrated disc compression (OR=1.8, 1.3-2.9). The psychosocial risk factors identified included perceptions of: i) a physically demanding job (OR=3.2, 1.9-5.7); ii) a poor workplace social environment (OR=2.8, 1.4-5.8); and iii) feeling “over-educated” for the job (OR=2.3, 1.1-5.2). Contrary to previous studies, better job satisfaction (OR=1.6, 1.1-2.4) and better coworker social support (OR=1.6, 1.1-2.3) also showed modest associations. Poor job control showed a borderline effect (OR=1.9, 0.9-4.1).

Conclusions: This study provides consistent evidence of an association between workplace biomechanical factors and LBP reported at work. Independent, though less consistent contributions were also found for psychosocial factors.
ACKNOWLEDGEMENTS

The study which forms the foundation of this thesis, the Institute for Work & Health-sponsored Integrated Study of Soft Tissue Sprains and Strains, could not have been completed without the active help and encouragement of a large number of people.¹

Although I bear primary responsibility for what appears in this dissertation, it could not have been written without the careful guidance and supervision of Dr. John Frank, Director of Research, at IWH as well as my thesis supervisor. Working with John has been an enormously rewarding learning experience for me. In all my dealings with him, he has continually afforded me the respect of a colleague, something which has allowed my professional confidence to grow unchecked. I am truly grateful for this boost to my career and my self-esteem.

My two other co-supervisors were also instrumental in the completion of this thesis. Dr. Harry Shannon, one of the co-investigators from IWH (and McMaster University), provided the primary biostatistical advice for the thesis, and was also a great help in getting me to develop the skills and mind-set required for coping with the unique challenges of occupational health research. My other supervisor, Dr. Lisa Badley, from the Arthritis in the Community Research Unit, at the Wellesley Hospital, was extremely helpful in pulling this dissertation together. Her clarity of thought and specificity of advice were extremely helpful in shaping the thesis into a presentable form.

A number of other people at IWH also deserve special thanks, including Sheilah

¹ During the data collection phase, the study was known as The Ontario Universities Back Pain Study, or OUBPS. Members of the OUBPS Study Group are (in alphabetical order): i) from IWH - Dorcas Beaton, Claire Bombardier, Sue Ferrier, John Frank, Sheilah Hogg-Johnson, Mickey Kerr, Michael Mondloch, Paul Peloso, Harry Shannon, Jonathan Smith, Stephen Stansfeld, Valerie Tarasuk; ii) from Waterloo - Dave Andrews, Patrick Neumann, Bob Norman, Richard Wells.
Hogg-Johnson, a senior biostatistician at IWH, Sue Ferrier, the study coordinator, and Dr. Claire Bombardier, a rheumatologist and clinical resource person for the overall IWH study. These three people were of particular help to me throughout the course of the study, especially Sheilah, who served as an unofficial, but extremely helpful biostatistical resource for the thesis. Sue’s contribution is also of particular note. Her skilful guidance of the data collection teams and careful tracking of the study subject, in addition to her overall input into the design of the study were much appreciated. Val Tarasuk, Dorcas Beaton, Michael Mondloch, and Jonathon Smith all played important roles in the execution of the overall IWH study and their contribution to the background work required to complete this thesis is deeply appreciated. Jonathon was also of particular assistance in the analysis of the physical exam data presented in the thesis. In addition to those listed above, special thanks goes out to John Salvini and Matt Mercer, members of the IWH interview team. As well, the assistance of Anne Sylvia Brooker in the analysis of WCB data is much appreciated.

Because of my additional role as the study liaison between the IWH and the University of Waterloo Occupational Biomechanics laboratory, special thanks has to go out to several people there, including the University of Waterloo co-investigators Dr. Bob Norman and Dr. Richard Wells, as well as Patrick Neumann, the overall coordinator of their contribution to the IWH study. Their patience, especially from Patrick, in dealing with a non-biomechanically trained graduate student epidemiologist, was particularly helpful and very much appreciated. Under Patrick’s leadership, a skilful and dedicated data collection team from Waterloo was able to complete an unprecedented number of biomechanical assessments in an enormously challenging environment, one of the largest automobile manufacturing sites in the world. Special thanks go to the many members of Patrick’s data collection team, including Mike Dobbyn, Mary Anne Edmondstone, Patrick
Ingelman, Brian Jeans, Jim Mylett, Geoff Outerbridge and Helen Woo.

On a personal note, I would like to acknowledge the support shown to me by family and by many friends and colleagues. Their faith in me was an inspiration to getting the thesis completed, especially after the number of setbacks that were faced along the way. The emotional support of my partner, Lisa Van Bussel deserves special attention. With the commitment required by this thesis, she has had to cope with an inordinate burden while trying to complete her own studies, and help look after our two children, Tecla and Jack. Their many smiles and warm hugs were often just the right tonic for someone struggling to the finish line.

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PREFACE

The Challenge
The aim of this study was to identify potentially amenable risk factors for work-related low back pain (LBP), the most common occupational health problem in North America. As with any doctoral dissertation, the challenges faced in seeing this aim through from conception to completion were numerous and persistent, appearing at every step along the way. Some of the unique challenges faced were undoubtedly the result of having to mesh scientific research principles with the practical realities of the work world. In the study setting, a large highly automated automobile manufacturing complex using a "just-in-time" production philosophy, the over-riding priority was clearly to assemble high quality vehicles with the minimum amount of problems and disruptions. Almost by definition, this study was itself a disruption, at least to the normal work day of every subject who participated, and to every one of their supervisors, as well as many other workers in their vicinity. Keeping the study running with a minimum of disruptions, while at the same time maintaining the interest of the stakeholders, was an immense challenge.

Working Within the "Integrated" Study
One of the main challenges in producing this final report stems from the fact that the case-control study described in this dissertation was part of a larger "Integrated Study" framework, sponsored by the Institute for Work & Health (IWH) and conducted in collaboration with occupational biomechanics experts from the University of Waterloo. The aim of the IWH research framework was to broaden the knowledge base on both the etiology and prognosis of work-related low-back pain. The main challenge created for this thesis by the merging of the two studies

* The full IWH "Integrated Study of Soft Tissue Strains and Sprains" protocol, containing other details not directly related to this thesis, is available from the Institute for Work & Health.

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was the temptation to make use of a mountain of available data that were not central to the thesis questions being addressed. This was particularly true for the data collected on the physical demands of work, since there were additional objectives related to new measurement tool development being addressed in the larger IWH study. As well, much of the data used to provide a detailed description of the study subjects, particularly the clinical profiles that establish the severity of the LBP cases, were available primarily because the combined IWH study collected them for the prognostic substudy, not the etiologic substudy that constitutes this thesis.

Figure P1: IWH Integrated Study of Low Back Pain (as originally designed).

Figure P1 outlines the core design of the combined IWH case-control and inception cohort study seeking to identify etiological factors influencing the onset of work-related LBP, as well as the identification of prognostic factors associated with LBP.
disability leading to time off work. All subjects received a baseline interview, usually within a week of enrolment, as well as a 6-month follow-up interview. Each subject, where possible, also had the physical demands of their job assessed by direct measurements of the workers doing their usual job, during normal work hours. Depending on their work-status, cases received multiple interviews during the six month interim, with the focus of these interviews on identifying factors that helped people return to work.

One of the aims of combining the two study designs was to minimize the effort required to do two separate studies, since it was expected that many of the subjects recruited for the case-control study would require at least three weeks off work because of their LBP. This was the main entry criterion for the prognostic cohort study.

Roles and Responsibilities

Although I was involved at the inception and planning stages of every part of the overall IW&H study, this thesis describes only the main risk factor identification component of the etiological case-control study, which compares the baseline data of newly reported cases of LBP with controls selected at random from the study base as the cases accrued. While the study presented in this dissertation was, by necessity, the culmination of the work of many people, from many different disciplines, the author bears primary responsibility for the main findings of this study. In order to clarify my role as one of the principal investigators from the outset of the overall IW&H study, and a PhD candidate in this very large and

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b Where necessitated by overlap, certain aspects of the overall IW&H study are mentioned in this dissertation, even though they may not be central to the thesis, which is based on the unmatched case-control design. For example, the job-matched control group shown in Figure P1, which was not directly a part of the main risk factor analysis, was a second, distinct control group in the overall IW&H study that was intended to provide a clearer understanding of the role of individual characteristics and individual worker's perceptions of the work environment in the etiology of LBP. As explained later, this thesis used these subjects only as providers of "proxy" data for information about the physical demands of work for cases who did not have the demands of their own job assessed.
expensive study, my specific tasks and responsibilities are outlined below:

i) provide the core background reviews of LBP risk factors, study design and methodologic issues;

ii) design of the data collection tools in collaboration with the other principal investigators, in particular the refinement of the main (baseline) questionnaire;

iii) serve as the main collaborator between IWH and the occupational biomechanical experts from the University of Waterloo;

iv) ensure that problems with data collection and subject management were properly dealt with, such as deciding who was or was not eligible to participate in each substudy (prognostic and etiologic), when such questions arose;

v) assisting in the collection of the biomechanical data at the study site, and more importantly, in its reduction from raw to usable formats at the University of Waterloo laboratories;

vi) ensuring the integrity of the baseline questionnaire data by dealing with coding and other data reduction problems as they arose;

vii) being the sole analyst for the etiologic risk factor data, responsible for merging the reduced data set from the combined IWH and University of Waterloo sources, as well as performing all analyses described in this report;

viii) being the primary author of all of the main reports for the etiological risk factor study, including those aimed specifically at the two main study stakeholders, the union and the company.
Figure P2. Outline of the Study Timeline.

Study History

As outlined in Figure P2, it has taken almost five years to arrive at the final stage of reporting on this large project. While some preliminary planning activity on the overall IWH study had been done before the work for this thesis began, most of this was focused on the objectives of the overall IWH study, and to a lesser extent on the design and background literature review for its prognostic component. After more than a year of preparation work, including many site visits and some pilot testing of questionnaires and measurement instruments, the original study site (a large steel mill) had to indefinitely defer active involvement with the study due to imminent downsizing of its workforce.

With such an intensive effort already invested, selecting a new study site that was suited to the basic thrust of the existing protocol was preferred over beginning the
design phase anew. After almost a year of extensive discussions with a number of potential sites, in which the author was personally involved, General Motors (GM) of Canada and the CAW, the union representing the GM workforce, agreed that the hourly-paid workforce at the main Oshawa vehicle assembly operation would serve as the study base.

Data collection began in early 1994, after a few additional months of pilot testing at the new site. Prior to the commencement of data collection, and continuing until it ceased, regular weekly or bi-weekly meeting were held with a study steering committee, consisting of the author, the other principal investigators, including the representatives of Waterloo biomechanics team, the company management and medical staff, and the union representative. Access to the study site coincided with a major re-engineering required to upgrade the car plant facilities (with 6500 employees) for the new model year. This restricted accrual to the 3500 truck plant employees, so that only 35% of the total study base was available for the first nine months of data collection.

After almost 2 years of pre-testing the study instruments, accruing the study subjects, and collecting the data, the field work phase of the study ended and the analysis began. (All of the details of the active phases of the study are described in the ensuing Methods Chapter.) After collecting the data, it took approximately a further six months to complete the reduction of the biomechanical data to the form usable for the study.

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This was a very time and labour intensive operation because of the scope of the data that was collected. It was not possible to speed this reduction phase up by separating out the small fraction of the variables being used for the main risk factor analysis described in this thesis because many of the final variables depended upon the entry and reduction of intervening factors. One of the objectives of the overall IWH study was to develop new, simpler methods for collecting physical demands data that might be of use in future prospective cohort studies. With this objective in mind, data was collected in several different methods, using a hierarchy of instruments and a "common metric" approach (as described in one of the published papers arising out of this study). The final biomechanical data set is unparalleled in richness, with data on the widest range of variables on the largest sample of study subjects ever collected from individual subjects in the field. This data set will serve as a very valuable resource for further analysis and measurement tool development studies.
Structure of the Document

The dissertation is divided into eight chapters: Chapter One introduces the study; Chapter Two describes the study background, including the rationale and objectives; Chapter Three reviews the published literature on the etiology and prevention of LBP; Chapter Four describes the features of the case-control design used; Chapter Five describes in detail the methods of the study; Chapter Six presents and scrutinizes the study's results; Chapter Seven provides the discussion and interpretation of the main findings; and finally, Chapter Eight presents the overall conclusions to the thesis.

A number of Appendices are also included with the dissertation. While not being essential to the contents of the main body of the document, they provide additional detail that will enhance the understanding of the methods used and therefore should improve the interpretation of the study's main findings.

As a final note, the overall IWH study, and in particular, the component described in this thesis, was truly a multidisciplinary effort. Epidemiologists, biostatisticians, occupational biomechanists, and physicians (including experts in family medicine, rheumatology and psychiatry) were all involved in the design and execution of the study. The interest in this study, across many disciplinary boundaries in many countries, has led to the intentional inclusion of some material that may seem superfluous for a PhD thesis in epidemiology. This minor disadvantage in parsimony was more than offset by exposure to the varied knowledge and skills of researchers from many disciplines. A direct consequence of this cooperative research approach has been the publication (or submission) of several papers in peer-reviewed journals and the presentation of many abstracts at scientific meetings.
INTRODUCTION

Study Synopsis

The main objective of the work described in this thesis was to identify risk factors associated with reporting low-back pain\(^*\) (LBP) at work. With its emphasis on measuring potentially remediable workplace factors, the eventual aim was to provide information to further the development of primary intervention strategies. The basic design features of the study are outlined in Figure 1.1.

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\(^*\) Unless otherwise noted, the phrase "low-back pain" refers to pain in the lumbar region of the back, typically without any neurological or radiological signs. (It excludes rare disorders such as disc herniation with neurological deficit.) This condition, also referred to as non-specific, idiopathic or mechanical low-back pain or "strain", is by far (>90%) the most commonly reported form of a range of back disorders observed in industrial settings. (Nachemson, 1994).
This thesis describes a case-control study of risk factors for low back pain that is reported to occupational health clinics in a large, modern manufacturing complex. To identify these risk factors, cases of newly reported LBP were compared with controls who were chosen at random from a study base population of approximately 10,000 hourly-paid workers at the General Motors automobile manufacturing facility in Oshawa, Ontario.

Subject accrual took place over a period of almost two years, using incidence density sampling of controls as cases accrued. Within a week of enrolment most subjects were interviewed at home to collect data on health-related and individual characteristics. Most of this information was collected to provide a detailed description of the study subjects, particularly the nature and extent of the cases' LBP, since formal medical examinations were not required for entry into the study. Subjects also received a short physical examination by a specially trained (non-clinician) interviewer to help document the clinical features of LBP.

The study interview also collected self-reported data from the subjects related to certain aspects of their psychosocial work environment, since these were considered to be possible risk factors. Finally, the physical demands of work were determined by a detailed biomechanical assessment of the subject's current job, defined as the job being performed at the time of reporting LBP for the cases, and at the time of recruitment for the controls. This assessment was usually done within a month of enrollment. It focused on peak and cumulative measures of specific forces generated in the lumbar spine when working, as well the loads handled and the working postures adopted, since these were all believed to be possible risk factors for LBP, on the basis of biomechanical theory and previous studies.


Study Rationale

The Burden of Illness

LBP is a common health problem that affects most people at some point in life.\textsuperscript{1,2} Estimates of the lifetime prevalence of LBP are fairly consistent — varying from 50-80%.\textsuperscript{3-7} The lifetime prevalence of serious LBP (lasting at least 2 weeks) has been estimated at 13.8\%.\textsuperscript{8} Estimates of the point prevalence of LBP in the general population vary considerably, possibly because of differences in defining the problem, with reported prevalence ranging from 4\% to 31\%.\textsuperscript{3-8,11} Although the percentage of the population that receives significant medical care or loses time from work due to LBP is much smaller than this — between 2\% and 5\% a year, LBP is still the predominant occupational health problem in Canada and the United States, accounting for about 20-30\% of all compensated injuries.\textsuperscript{2,12-15} In some jurisdictions close to 50\% of all direct compensation costs have been attributed to LBP.\textsuperscript{12} It is estimated that the Ontario Workers Compensation Board paid out close to 1 billion dollars for about 100,000 lost-time and non-lost-time LBP claims in 1995.\textsuperscript{16}

Although most people recover quickly from an acute episode of LBP, it is one of the most common reasons for visits to family physicians and it is also a leading cause of chronic disability in the general population, especially in younger adults (i.e. before middle age).\textsuperscript{17,18}

While the enormous social, financial and personal toll attributable to LBP has provided more than sufficient rationale for extensive etiologic and prognostic research, a great deal remains to be learned about its origins (pathogenesis), its causes (etiology), and what affects its clinical course (prognosis).
Defining the Condition

Low back pain, is not an easy condition to confirm diagnostically. There is no clear underlying medical pathology observed for the vast majority of reported cases, even when investigated by the most advanced medical imaging methods. To make a diagnosis, physicians typically rely on the descriptions of symptoms and functional impairment provided by their patients. Even the most thorough clinical exam can identify only a minor subset of subjects with any objectively demonstrable pathology, mostly patients with sciatica, where there is typically sciatic nerve impingement that leads to pain radiating from the back down into the lower legs.

The absence of any definitive LBP diagnostic procedure, combined with the substantial functional impairment that often accompanies LBP, has produced a climate of suspicion and mistrust, not only regarding the presence of the pain itself, but also its attribution to the work environment. The inability of the medical profession to convincingly identify a pathology for most LBP cases (especially one that explains duration of disability), combined with its high population prevalence and a lack of definitive data on work-related risk factors (largely because of the enormous methodological and logistical problems inherent in performing workplace etiological studies of LBP) may have contributed to the development of a widely held opinion that LBP is an unavoidable, ubiquitous condition that will afflict almost everyone at some point in their life, regardless of their work environment.

One of the aims of this study was therefore to specifically address this controversy regarding workplace attribution of LBP, and in so doing, establish if there are sufficient grounds for developing primary prevention strategies. This dissertation describes in detail the methodology and results of one of the largest etiologic studies of LBP to date, which made use of detailed measurements on a full range of...
potential risk factors in order to help untangle the complex etiologic web surrounding LBP at work.

**Study Objectives**

The specific intent of this study was not primarily to uncover the biological origins of back pain itself. Rather, the study's main goal was to identify work-related factors that increase the risk of developing LBP, with particular attention being paid to biomechanical and psychosocial aspects of work that might be amenable to change. This study was designed to specifically address two major methodologic concerns: i) the need to have exposure assessments that measure the relevant biomechanical and psychosocial work-related factors in all subjects; and ii) the need to have assessment of exposures at the individual level, and as comprehensive as possible, particularly the biomechanical demands of work.

**Primary Study Objective**

To identify potentially modifiable components of work, in particular the relevant biomechanical and psychosocial aspects of the job, associated with an increased risk of reporting LBP in an occupational setting.

**Research Questions**

1. What are the risk factors for worksite-reported, non-specific LBP?

   In particular, when measured at the individual level, how do direct measures of job-related biomechanical exposures and self-reported perceptions of the psychosocial work environment affect the risk of reporting LBP at work, after individual worker characteristics have been accounted for in a multivariable analysis?
2. Did the use of "reported" LBP as the case definition, without any formal medical examination to confirm the presence of LBP, result in a case series that was representative of typical acute LBP patients, as determined in other studies?

3. Did the use of proxy biomechanical data from job-matched controls, for cases who did not have the physical demands of their own job assessed, significantly alter (especially attenuate) the observed risk estimates from Question #1 - i.e. was there significant exposure misclassification entailed in their use?

4. Did the inclusion of controls with a measurable level of LBP at the time of the psychosocial risk factor interview, significantly alter (attenuate) the observed risk estimates from Question #1 - i.e. was their significant case misclassification entailed in their use?

To address Question #1, workers with LBP (the cases), newly reported to one of the onsite occupational health clinics in a large automobile manufacturing complex are compared with a group of controls randomly chosen from the study base of all hourly-paid workers. Special emphasis was given to the assessment of physical loading on the lumbar spine through the use of state-of-the-art direct measurements of forces and postures experienced at work by individual study subjects. In addition to these workplace assessments, an interview-assisted questionnaire was used to collect data on possible job-related psychosocial risk factors, individual characteristics, and clinical variables. The ultimate goal of the study was to identify variables that might be suitable targets for workplace primary prevention efforts aimed at reducing the rate of new LBP incidents.
To address Question #2, a detailed description of the clinical features of the case population is presented. The cases and controls are also compared on a number of clinical variables and individual characteristics to determine if there were any other significant differences between the two groups that might impact on the interpretation of the results of addressing Question #1.

Questions #3 and #4 are addressed by sensitivity-type analyses of the final statistical model obtained when answering Question #1. For Question #3, the cases with proxy data were removed and the model re-run to assess the effect of proxy data use. In addition, the validity of the assumption of interchangeability of proxy and case data was also examined, by determining the level of agreement between a sub-group of cases and their job-matched control pairs in which there was complete data available on the biomechanical exposures that were involved in the proxy substitutions. While not a main study question, the level of agreement between the cases and the job-matched controls on the self-reported psychosocial variables was also examined. The existence of large differences between cases and job-matched controls on responses to these questions could be an indication of possible bias that would have to be accounted for when interpreting the final results.

For Question #4, controls with chronic or acute LBP (that was unreported to the medical clinics) were excluded and the final model from Question #1 was re-run to observe the effects on the regression parameters. Since LBP can be either acute or chronic, two separate analyses of this type were done - one excluding controls with a significant amount of LBP in the past year, the other excluding controls if they indicated they had LBP during the week prior to the interview.\(^b\)

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\(^b\) As explained later in the thesis, potential control subjects were not excluded if their interview responses indicated they had some degree of LBP. This was done mainly for reasons of acceptance of the study in the workforce and generalizability of the results, since previous studies (see Punnett et al., 1991 - reference #14, on page 17) indicated that a large proportion of the workers would likely have some degree of LBP, though not serious enough to report it at work.
Bibliography - INTRODUCTION


BACKGROUND

Diverging Conceptual Models of LBP Etiology

To better convey the scientific context of this dissertation, the following section briefly summarizes two divergent conceptual models evident in the literature concerning occupational LBP etiology. These models are summarized in Figure 2.1 shown below.¹

![Diagram showing two conceptual models of occupational low back pain: Biomechanical Model and Psychosocial Model]

Figure 2.1: Underlying Conceptual Models of Occupational Low Back Pain

The focus of the biomechanical model of LBP is organic soft tissue damage in the lumbar region of the back that is believed to be caused by excessive exposure to

¹ Much of the background information presented here is based on a co-authored paper describing the problems and conceptual models of prior LBP etiologic (and prognostic) research. (Frank et al. 1995) In a similar way, the literature review draws heavily upon my contribution to another co-authored paper published late last year, which was one part of a two part monograph on occupational low back pain. (Frank et al. 1996) These publications, as well as two others have arisen out of the work for this thesis. One of these additional papers discusses general issues of design and interpretation for etiologic studies of LBP (Bombardier et al., 1994), while the other deals more specifically with the aforementioned "common metric" strategy adopted for assessing the workplace biomechanical risk factors examined in this study (Wells et al., 1997).
workplace biomechanical stressors, such as compressive forces in the lumbar spine generated by heavy lifting. Variables without an obvious connection to the physical demands of the work, including psychosocial factors such as job control or social support on the job, are typically not examined in studies based on this biomechanical model. The emphasis here is on the work rather than on the worker. Interventions based on this model would focus mainly on primary prevention - i.e. preventing the onset of pain or tissue damage - by ergonomically improving the design of work.

In the psychosocial model, occupational LBP is regarded as a social phenomenon of industrialized countries that is more likely a consequence of the psychosocial status of the worker and/or their work environment than the result of excessive work-related physical demands. Although not specifically "blaming" workers per se for the current epidemic of LBP in industrialized countries, the focus of this model has often tended to be limited to characteristics of the worker, rather than the work. Interventions based on a worker-centred version of the psychosocial back pain model tend to be focused more on secondary prevention efforts, since onset is considered unavoidable. In this model of LBP, the aim is to prevent disability (and its sequelae, especially prolonged time on workers' compensation benefits), after the onset of pain has already begun.

The biomechanical model dominated early etiological research on occupational low-back pain. Its focus has been on the identification of workplace biomechanical stressors that can lead to LBP because of tissue damage in the lumbar spine and supporting soft tissues. Despite extensive laboratory work, the precise site and mechanism of this tissue damage, or injury, is still not known. It may be a response to an acute stress such as trauma, where the tissue tolerance is suddenly exceeded. Or it may be the result of chronic exposure, where tissue tolerance is gradually
decreased over time to a point where previously acceptable biomechanical loads now result in a LBP response.\(^9\)

LBP may be a direct consequence of excessive biomechanical exposures, such as the failure of end plates in the intervertebral discs observed in cadaverous spines when exposed to high compressive forces\(^{10}\), or it may be an indirect effect, whereby tissues are possibly affected by hormonal responses to more chronic stressors. This type of indirect mechanism has been discussed for the “Cinderella” hypothesis, where electromyography (EMG) studies have suggested that some muscle tissue may show increased EMG activity after direct physical load exposure has ceased.\(^{11}\) This study also demonstrated that muscle groups can remain refractory to stimulation/activation after prolonged use.

In most of the published research with a biomechanical orientation, exposure to potential psychosocial risk factors, such as perceived job control or social support on the job, is rarely assessed. Early research, such as that by Magora and Chaffin, focused primarily on the "heaviness" of work, and lifting in particular.\(^{12,13}\) Recently, some studies have examined more specific components of work, especially trunk postures and motions.\(^{14,15}\) As a group, the studies focusing solely on the physical demands of work have shown a fairly high level of consistency in their results, with more physically demanding jobs generally reported as being associated with greater LBP risk.

The body of evidence in support of the psychosocial model of LBP etiology, as well as the theoretical and conceptual underpinnings of the model, are not nearly as well developed as they are for the biomechanical model.\(^{16}\) One of the central contributing components of this model, and one that receives extensive attention from this study, has come from Karasek, with later modifications in conjunction
with Theorell.\textsuperscript{17} Their demand-control-support model of work-related psychosocial stress has been widely studied, particularly for cardiovascular disease (CVD) outcomes in occupational settings.\textsuperscript{18-20} It has only recently been extended to other health outcomes, most notably musculoskeletal research.\textsuperscript{21,22}

Research based on the Karasek-Theorell model has established a clear but modest (each with a RR about 2) association between CVD and the imbalance between the psychological demands of work, the degree of control available to the worker (presumably to modify these demands) and the workplace social support network available to mediate the demands.\textsuperscript{23} People working under "high strain" conditions, with high demand, low control and low social support, are at clinically significantly greater risk for CVD, even after adjusting for established risk factors such as smoking.\textsuperscript{24} The relationship is not yet clearly established for musculoskeletal conditions, possibly because fewer studies have examined it, and the outcome is less clearly defined than CVD.\textsuperscript{16}

Some of the controversy surrounding the acceptance of psychosocial variables as risk factors for LBP may be the result of the difficulty in conceptualizing a causal mechanism. Recently, studies have begun to explore the biological mechanisms that may explain the association between LBP and psychological stressors. Although the evidence is still very limited, there is some new research, particularly from EMG studies, indicating that direct biological effects of "stress" are possible on the musculoskeletal system.\textsuperscript{25,26} Some of these effects are similar to those seen from biomechanical stressors\textsuperscript{27} - e.g. increased muscle tension - while others may be responses specific to psychological stressors - e.g. increased blood levels of cortisol or changes to the pain receptors.\textsuperscript{22} It is also likely that some factors labelled as psychosocial variables could have an indirect effect on LBP risk by modifying exposure to biomechanical risk factors. This overlap, or surrogate exposure concept,
was confirmed in a thorough review of the epidemiologic literature on psychosocial risk factors for LBP, which concluded that the "studies do not present conclusive evidence [of a link between psychosocial factors and LBP] because of high correlations between psychological factors and physical load, and difficulties [in measuring] dependent and independent variables".  

As shown in Figure 2.2, the possible injury mechanisms underlying the two main conceptual models for LBP, outlined above, may be the result of direct and/or indirect effects from exposure to either type of risk factor - psychosocial or biomechanical. The uncertainty surrounding these mechanisms, and the restrictions imposed by the rather narrow conceptual underpinnings of much of the prior LBP etiologic research, resulted in the broad-based approach to assessing workplace exposures that was adopted by the study described in this dissertation. It is likely that these divergent conceptual models for LBP etiology have contributed to the current state of confusion regarding the relative importance of biomechanical and psychosocial workplace factors in the genesis of LBP.

Figure 2.2: Possible Mechanisms for Back Pain Injury
Bibliography - BACKGROUND


LITERATURE REVIEW

Objective
The first part of the review is intended to provide readers with an understanding of current knowledge of risk factors for occupational LBP, particularly as they relate to the variables examined in this thesis. The second part of the review is meant to address the concern expressed by some researchers that efforts aimed at primary prevention of LBP may be futile, and hence by extension, etiologic studies therefore unnecessary.1,2

Scope
The present review is deliberately limited in its scope by focusing on the exposures most relevant to occupational settings. Particular emphasis was given to suspected biomechanical and psychosocial risk factors, with the review focusing on the results of epidemiologic studies rather than laboratory studies, case reports or expert opinion. A structured, critical review of the evidence concerning LBP and whole body vibration has been previously published3, while a thorough review of the methods used for workplace biomechanical exposure assessment has also been recently published.4 Bongers et al. have extensively reviewed the evidence concerning psychosocial risk factors for occupational LBP.5 Several reviews of the general epidemiology of LBP are also available.6-10

Risk Factors
Winkel and Mathiasson11 describe three categories of risk factors for back pain: i) individual, such as a person's weight, a history of prior LBP, and smoking habits; ii) physical, such as lifting and posture (referred to in this dissertation as biomechanical risk factors); and iii) psychosocial, such as job control and job satisfaction. The epidemiologic evidence concerning factors of relevance for each
of these three risk factor categories is reviewed below. This evidence is also briefly summarized in Table 3.1 shown below.

<table>
<thead>
<tr>
<th>Estimated Strength of Association</th>
<th>Individual Risk Factorsb (Reference #)</th>
<th>Biomechanical Risk Factorsb (Reference #)</th>
<th>Psychosocial Risk Factorsb (Reference #)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak (RR = 1-2)</td>
<td>smoking (23)</td>
<td>-</td>
<td>job dissatisfaction (43)</td>
</tr>
<tr>
<td></td>
<td>obesity (15)</td>
<td></td>
<td>work pace (5,17)</td>
</tr>
<tr>
<td></td>
<td>female (17)</td>
<td></td>
<td>job control (5,17,42)</td>
</tr>
<tr>
<td></td>
<td>age (15-18)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate (RR = 3-4)</td>
<td>prior LBP history (12,13,33)</td>
<td>heavy lifting (36,37)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>whole body vibration (3)</td>
<td></td>
</tr>
<tr>
<td>Strong (RR ≥ 5)</td>
<td>-</td>
<td>spinal loading (35)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>postural stress (33,35)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>trunk motion (35)</td>
<td></td>
</tr>
</tbody>
</table>

Caveats on the interpretation of risk estimators from different studies:

a "Weak" strength of association indicates that exposure to the factor would likely no more than double the risk of developing LBP. "Moderate" strength indicates a tripling to quadrupling of risk, while a "Strong" association indicates that exposure to the factor is likely to greatly increase the risk of developing LBP. The level of these associations was based on a review of values reported in the published literature and represent the larger values found. They are not the result of an exhaustive combining of data from actual studies (i.e., not a meta-analysis). The relative risk (RR) or odds ratio (OR) indicates how much more often those with a risk factor suffered from LBP than those without the factor. The values of the RR's are not adjusted for differences in study populations, especially differences regarding the proportion of subjects exposed to the particular risk factor(s).

b For most variables, the RR indicates the risk of having the factor versus not having it – e.g., heavy lifting versus no heavy lifting. In some studies, multilevel comparisons are made (e.g., a heaviness scale from 1-5). The estimates shown above do not adjust for these different analytic strategies. Comparing only high risk to low risk groups could inflate the size of the observed RR, compared to RR estimates from other studies not using the same analytic strategy.

TABLE 3.1: Risk factors for the occurrence of occupational low back pain (modified after Frank and Kerr et al., 1996).

i) Individual Factors

Prior LBP

The factor with the most consistent association, and perhaps the only established LBP risk factor, is a history of prior LBP, with previous episodes of LBP shown to be predictive of who will report it in the future.12,13. Due to the lack of any clear
underlying pathology for most LBP, the mechanism for this association remains unclear. As a direct biological influence, it may be indicative of a reduced threshold for injury or pain for lumbar spinal tissue that has been previously damaged. As an indirect marker of exposure, the association between prior LBP and future LBP could also be the result of a high risk exposure history that has remained consistent over time. For example, if the physical workload was contributing to the onset of LBP, and it remained unchanged at the LBP-inducing level, then LBP risk would obviously remain at an elevated level as well, resulting in repeated LBP episodes. This hypothesis remains the subject of conjecture however, since no studies have been able to document long term cumulative exposure history well enough to control for it in an epidemiological analysis, nor is the appropriate exposure metric yet known to permit such a study.

Age
The association with age is not well established, but the results of studies have shown some consistency for the relationship in younger and middle-aged adults, with risk appearing to increase with age. However, this association often disappears when studies control for other factors, such as physical work load. The weakness of the putative association between age and LBP is also demonstrated by the fact that some studies have reported a negative association, particularly among older workforces, where the younger adults were more likely to file a compensation claim for LBP or report LBP at work. This increased risk in younger age may be an effect of heavier work load or lack of experience, though neither of these possible explanations was accounted for in the observed studies.

Other factors
Even less well established are the associations between LBP and obesity, cigarette smoking and female gender, all of which have been suggested as possibly increasing
Finally, there is at best contradictory epidemiological evidence supporting an association between the occurrence of LBP and general fitness, physical activity or muscular strength level. Few of these other suspected risk factors are readily modifiable, especially in the workplace, and thus are of limited potential utility in prevention strategies specific to LBP, although fitness and anti-smoking campaigns certainly have considerable potential in the prevention of other health outcomes, most notably cancer and CVD. As a final note, "abnormalities" observed on spinal radiographs, particularly as used in preplacement screening programs in workplace settings, have now been clearly shown to be of no value in predicting who will develop disabling LBP at work. It appears as though attempts at identifying spinal deformities associated with typical LBP, even when using the most modern and sophisticated imaging equipment, are of no better etiologic value than they are of diagnostic value.

ii) Biomechanical (Physical) Factors

Assessing Exposure

Most of the published literature examining biomechanical risk factors for LBP consists of cross-sectional studies, such as surveys. The use of error-prone measurement instruments, such as indirect (subjective) exposure measures from self-reported questionnaires, and overly simple exposure categories based on job titles, are common features of prior LBP etiologic research. Studies using direct (objective) measurements of biomechanical exposures in the workplace are rare. The few studies using such methods are described below.

Studies with Detailed Exposure Assessments

In preparing this review, only two other epidemiologic studies were found that conducted workplace exposure assessments that included direct measurements of biomechanical load on workers with and without LBP. One was a case-control
study of low back pain in automobile assembly workers in Michigan, the other was the "Boeing Study", a large prospective cohort study of LBP in airplane assembly workers in Seattle. The Boeing study is discussed later, under the psychosocial risk factor heading.

The case-control study by Punnett et al., relied mostly on video-taped posture analysis to conclude that workers who spent more time in non-neutral postures, defined as a posture more than 20 degrees from a standing upright position, were at significantly increased risk of LBP. This study using individual assessments of the trunk postures in 95 cases of LBP (newly reported to company; no repeat visits) and 124 controls (no LBP report; no LBP symptoms at interview) demonstrated a large increase in LBP risk (OR=8.09, 95% CI 1.5 - 44.0) from prolonged bending and/or twisting on the job, after adjusting for age, heavy lifting and prior LBP. Using an analysis limited only to workers with "heavy" lifting, this study did not find an effect for peak disc compression, the only spinal biomechanical force examined. In fact, controls may have had higher peak disc compression than cases (control \( \bar{x} = 2437 \) N, case \( \bar{x} = 1938 \) N, \( p=0.16 \)). The lack of statistical significance for this difference may have been attributable to the low sample size used, with only 21 cases and 16 controls eligible for the analysis.

There may be some concern with the way that the OR results were presented in this study. The continuously scaled variable, time in non-neutral postures, was expressed in terms of a 0 versus 100% exposure difference to estimate the OR from the final logistic regression model. Using this method to express the OR may overstate the strength of the association, as few workers would likely be at these extremes of the distribution, as evidenced by the wide confidence intervals.\(^4\)

\(^4\) This thesis chose to use a more traditional method of expressing OR's for continuously scaled covariates, by using the unit difference between the 75th and 25th percentiles, also called the Q3-Q1 range, of the random control distribution.
Although not a typical epidemiological study, a cross-sectional study by Marras et al., conducted even more detailed workplace assessments than the Punnett et al. study, including estimates of moments and trunk motion variables, in particular the speed at which the back moved during work activities.\(^{35}\) This study also demonstrated a strongly increased risk of LBP with higher biomechanical demands, with an estimated combined OR for the final model (a combination of lifting rate, load moment and trunk motion) of 10.7 (90\% CI 4.9, 23.6). However, it did not enrol workers with and without LBP. Instead it compared people working in "high" and "low" risk jobs, with the risk category determined by how frequently compensation claims for LBP were made in the three year period prior to the study. Only "repetitive jobs" involving manual materials handling were included in the study. Estimates of forces in the lumbar spine, other than moment, were not calculated.

A number of other studies have also demonstrated an association between LBP and the physical demands of work, especially in relation to heavy lifting, patient handling (among nurses), or categorized work activities.\(^{22,36,37}\) However, these studies have all relied upon self-reported evaluations of these demands, either at interview or by questionnaire - none used direct assessment of the exposures.

Inadequate assessment of exposures is therefore common, given that indirect measurement tools are cheap and easy to administer while, direct measures are very expensive and pose a serious logistical challenge when large numbers of subjects are involved in a complex work environment.\(^{38}\) When workplace exposures are inaccurately measured (i.e., with extensive error or misclassification) the ability of a study to establish risk factor associations is clearly reduced.\(^{39}\)

In addition to not measuring exposures properly, studies may not examine certain factors at all, thereby eliminating the possibility that an association can be
established. Such "errors of omission" can occur when a study's underlying conceptual model of LBP (as presented in the Background chapter) leads to restricted exposure assessments. The narrow focus that can result would have clear consequences for determining the relative importance of work-related versus worker-related factors, since this can only be sorted out when both types of factors are measured appropriately.

Taken individually, most of the published studies on LBP provide only weak epidemiological evidence of causation. However, two observations support the conclusion that there is reasonably good evidence for a causal relationship between back problems and workplace biomechanical exposures: i) the consistency with which certain self-reported variables, such as heavy lifting, manual material handling, and "heavy physical load" have been reported over many studies as being linked to LBP; and ii) the strength of the associations observed for more objectively measurable characteristics of the physical demands of work, such as whole body vibration, trunk motion variables, estimates of spinal loading forces or the time spent in awkward postures.

Although very few studies that directly examined biomechanical risk factors have also adequately addressed the likely interaction between these and workplace psychosocial risk factors, the overall quality of these more recent studies and the strengths of the associations they report when biomechanical factors are appropriately measured clearly indicates the importance of the physical demands of work in the etiology of LBP. Only a few studies have attempted to simultaneously measure biomechanical and psychosocial risk factors. In general, these studies report that biomechanical factors account for a larger proportion of the observed variance than did psychosocial factors, once again underscoring the risk associated with the physical demands of work. These studies are discussed.
iii) Psychosocial Factors

There is limited but growing empirical evidence linking psychosocial risk factors to the occurrence of LBP. Despite concern that the role for psychosocial factors may be limited to effect modification rather than being risk factors per se, a recent review identified a number of variables, including monotonous work, high perceived workload and time-pressure have been reported as being possible risk factors for musculoskeletal disorders, including LBP.5

The possibility that psychosocial factors may have an independent contribution to the etiology of LBP has been substantiated recently by an analysis of routinely collected survey data in the Netherlands, that reported an association between psychosocial stressors (high work pace and lack of intellectual discretion) and musculoskeletal complaints including back pain, even after taking (self-reported) physical work stressors and worker characteristics into account.17 Physical work load demonstrated a strong independent association with LBP on its own as well.

Further support for a link between psychosocial factors and soft-tissue musculoskeletal problems at work (although not specifically back pain) comes from a study by Faucett and Rempel in video display terminal (VDT) operators at a large US newspaper.42 Like the Dutch study described above, these authors reported separate, independent associations between biomechanical aspects of work (keyboard height, posture), job-related psychosocial factors (workload, decision latitude and support) and the presence of musculoskeletal symptoms. However, as with the Dutch study, the strength of the association was generally higher for biomechanical factors than that observed for psychosocial factors. This research has highlighted the importance of examining the interplay between psychosocial and biomechanical risk factors.
Finally, the Boeing Study, possibly the most detailed LBP research effort yet completed, is often cited to support the association between job-related psychosocial factors and LBP. The main finding of this prospective three-year cohort study was that, apart from a prior history of LBP reports, worker dissatisfaction with the job tasks was the only work-related risk factor associated with subsequent reporting of LBP. None of the variables assessing the physical demands of work significantly predicted who reported back pain. However, it is possible that the ability of this study to identify biomechanical risk factors was limited by misclassification error resulting from the assignment of exposure data from group-level biomechanical assessments to the study subjects, rather than the collection of data for each individual doing his/her own job.

It should also be noted that the final statistical model of this study could predict only a small proportion of the observed cases even when all measured risk factors were combined. Given these caveats, and the paucity of corroborative studies, it may be premature to conclude that job dissatisfaction per se is a more important predictor of LBP than the biomechanical demands of work.

**Risk Factor Summary**

Table 3.1, on page 20, summarizes the most likely factors for LBP, that appear to have the most consistent evidence. None but prior LBP history can be considered as established risk factors based on criteria of causation. Although the overall quality of the published evidence on risk factors is limited, it seems fair to say that there is sufficient evidence (especially from recent studies of biomechanical risk factors) to conclude that workplace exposures are contributing to the onset of occupational LBP. Hence there is a need to identify specific, modifiable components

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* Biomechanical data were collected for the Boeing study only for "job types" employing 20 or more workers. The remaining subjects were assigned the exposure values based on this site-specific job classification scheme. (See Bigos et al. 1992)
of work that may be causally associated with the problem, so that effective interventions can be mounted. Future research should therefore focus on making detailed measurements of workplace exposures, from both the biomechanical and psychosocial realms, so that these components can be untangled.

The Effectiveness of Interventions

New and better etiologic studies to identify LBP risk factors may be academically satisfying, but they are of little use if nothing can be done with the information that is obtained. Thus, the limited published literature on primary prevention of LBP was reviewed to assess the potential for the results of this thesis to contribute to the development of interventions that might reduce LBP incidence.

Demonstrating the scientific effectiveness of workplace interventions — did the "package" achieve its desired effect(s) — is a difficult challenge. Effectiveness depends on a number of factors, only some of which are under the control of the researchers: i) efficacy — e.g., safety glasses do prevent eye injury if properly used; ii) coverage - e.g., all workers were provided with safety glasses; iii) compliance - e.g., workers wore the glasses; and iv) outcome - e.g., all eye injuries were recorded. Researchers must also contend with many extraneous factors that might influence effectiveness, such as economic disruptions in the workplace (e.g., layoffs), industrial engineering factors (product or processing changes), and labour-management problems (e.g., strikes). Criticisms concerning the paucity of published reports describing properly evaluated workplace interventions need to be viewed with these problems in mind.

Primary prevention measures focus on reducing the incidence of new episodes of LBP rather than reducing disability or work absenteeism in people who already have a back problem. To achieve their goal, primary prevention interventions typically
follow one of two paths:

i) they aim to change the worker by increasing their "resistance" to back injury (e.g., by teaching "proper" lifting techniques to material handlers); or

ii) they aim to change the work by reducing the physical demands of work, usually through ergonomic re-design of tasks (e.g., the reduction of patient-lifting loads for nurses through the use of mechanical hoists).

There is clearly some degree of overlap produced by using such simple two categories but they help to broadly classify most published workplace prevention efforts. Further information on a more detailed method of classifying prevention concepts and strategies can be found elsewhere.41

i) Changing the Worker:

Programs aimed at reducing LBP incidence through attempts to change individual workers are the most frequently reported type of interventions.45 Some of the most common approaches for these interventions include: job training (e.g., lifting technique); behaviour modification (e.g., safety education and injury awareness programs); or increasing trunk strength (e.g., exercise).41 The underlying assumption of interventions to increase the resistance of workers to LBP is that better conditioning and care of the back will translate into a reduced risk of onset for LBP. There is a danger that interventions based on this assumption can be perceived negatively as a form of victim blaming – i.e., such programs imply that the problem of LBP (and especially its related disability) are not so much due to the work being done as to the workers doing it.46 Published intervention studies rarely
discuss whether the investigators took into account this concern among potential study subjects. It is possible that failure to gain sufficient worker support for an intervention study’s implicit conceptual model can seriously hinder the demonstration of the studied program’s effectiveness.

Many workplace interventions aimed primarily at changing the workforce have produced mixed results. For example, in a study where one group of nurses received enhanced training on patient-handling skills while the other group had traditional training, Videman et al. did observe an increased risk of back injury for nurses in either group who were individually rated as having “poor” patient handling skills. However, when the two intervention groups were compared, there was no overall difference observed in back pain rates between nurses receiving the enhanced training and those not receiving it. Somehow knowledge about lifting seemed important but the educational intervention was ineffective.47

The evidence supporting the use of back braces in industry is also conflicting. The National Institute of Safety and Health (NIOSH) in the US has concluded that these devices have not been clearly shown to be effective in preventing injury, or reducing disability.48 However, a recent study in California has reported a significant reduction (34%) in LBP claims which the authors attribute to mandatory use of back belts during manual materials handling.49 This large historical cohort study that appears to have taken advantage of a “natural experiment” to investigate the preventive value of lumbar back belts in healthy employees (i.e. primary prevention). The data were collected from the employment records of Home Depot retail stores (the number of employees involved eventually reached 36,000). Belt effectiveness was assessed as the difference in the company’s WCB claim rate for back pain before/after the use of belts. The introduction of the belts was accompanied by a "back belt policy", which may have included a training
component and/or other factors possibly affecting rates. In fact, the authors seem to slip between the phrases back belt use and back belt policy throughout the article, thus it is sometimes unclear if they are crediting the results to the policy or the belts themselves. Changes to the compensation system in California over the study time frame, which would have made it harder to get compensation of back claims, may not have been accounted for. Finally, the benefits seen were not distributed as expected, with the least "exposed" group showing the largest effect, the most exposed only modest benefit, and the middle group showing none. NIOSH has reviewed this study and not changed their guarded comments about the unproven benefits of back belts. (F. Blosser, NIOSH, personal communication)

Exercise programs have demonstrated some promise, at least in health care settings. Nursing personnel in a Swedish geriatric hospital randomized to receive exercise instruction during working hours reported fewer new episodes of back pain (as well as reduced pain-related absenteeism) compared to a control group without the exercise regimen. Finally, a controversial form of "intervention" aimed at reducing the frequency of LBP is pre-placement screening of individuals for job fitness. Most of these screening efforts, including radiological examinations, medical examinations and generic pre-employment strength tests, have been ineffective in predicting who will subsequently develop disabling LBP on the job. Such programs also need to be carefully considered in the context of human rights and employment equity legislation.

**ii) Changing the Work:**
Demonstrating the effectiveness of ergonomic interventions to reduce back pain in the workplace has proven to be a difficult challenge. Despite the extensive biomechanical laboratory evidence to suggest that such changes should be effective, very few interventions have produced a clear reduction in LBP incidence
when evaluated by rigorous scientific criteria.\textsuperscript{32,44,51,55,56} Ergonomists have had a difficult time trying to translate their science's laboratory and conceptual promise into an observable and reliable reduction in LBP incidence. A similar criticism could also be directed towards clinicians regarding the absence of any demonstrably effective treatment protocols for early LBP, despite the availability and utilization of enormous financial and academic resources. Back pain is, however, a difficult condition to study, and the workplace is a difficult laboratory in which to study – a combination that has possibly stymied many research efforts.

A number of factors may also be interacting to diminish the effectiveness of predominantly ergonomic interventions. These problems, though not exclusive to ergonomic interventions, include: i) difficulty in identifying what needs to be changed (specific risk factors for injury); ii) the high cost of the interventions – redesigning the workplace for large numbers of employees can be expensive when aimed at preventing or accommodating common conditions such as LBP; iii) lack of underlying commitment from workers and/or management to the principles of ergonomics; iv) uncertainty concerning how to best monitor the effects (outcomes); and v) relatively weak study designs – before/after studies are common, while randomized trials are rare. With respect to this last issue, there may be no easy answer. Like many public health or community-based interventions, ergonomics programs are typically executed at a social level of aggregation - in this case the workplace level. There are major feasibility and cost hurdles facing any attempt to randomize large numbers of workplaces in a controlled prevention trial.\textsuperscript{44,57}

Despite these difficulties, a few studies have managed to report a direct reduction in the frequency of LBP. An ergonomic intervention in nursing home personnel has reported a 40% reduction in the number of LBP events in the period after initiating the study, as well as improvements in perceived exertion and measured loads.\textsuperscript{58}
However, this was a small study (N=47) with only limited follow-up of the personnel (four months post-intervention).

A similar reduction in sick leave due to musculoskeletal problems (including but not restricted to back problems) was reported from an extensive ergonomic intervention over 17 years (1967-84) in a small telecommunications factory in Norway. This study also assigned a very favourable cost-benefit ratio to the intervention. However, as with the previous study, the analysis was based on a before/after comparison, without a control group. Also, the fact that this intervention involved such a long study period means that it would have been difficult to account fully for many other intervening factors that could have affected the results, such as changes in the production rates, methods or materials used.

Recently, an intervention study was conducted among municipal workers in California that randomly assigned four of six divisions to a workplace ergonomic intervention. The two other unrandomized divisions were used as a control group. This study reported a "modest" reduction in back pain incidence, as well as improvements in job satisfaction and health behaviours. Cost-benefit analysis showed a 179% return (US$160,000) on the program investment. Finally, a new study from Manitoba, while initially designed primarily as a secondary prevention study to reduce the amount of lost-time due to back pain in nursing staff of a teaching hospital, also documented substantial reductions on the incidence of lost-time claims, possibly due to "spill-over effects" of ergonomic interventions on the wards, aimed primarily at improving injured nurses return-to-work.

**Intervention Summary**

Only a few studies were found that were able to demonstrate a reduction in LBP rates associated with interventions in the workplace, and not all may pass muster
when subjected to rigorous evaluation criteria. However, a number of other interventions have shown an effect on intermediary outcomes, such as a reduction in biomechanically measured workloads. Although not included in this epidemiological review, a few recent examples of such studies include ergonomic interventions to improve workloads in the woodworking industry, to redesign the shoulder bag for mail carriers, and to redesign the ergonomics of the interior of police cruisers.\textsuperscript{63-65}

**Conclusions**

Several reviews of LBP epidemiology have concluded that there is considerable potential for primary preventive interventions to reduce the overall burden of illness associated with LBP.\textsuperscript{7,8,45} However, the empirical evidence to support this conclusion remains limited.\textsuperscript{48} The dearth of rigorous evaluations for primary preventive LBP interventions may be partly attributable to the logistical difficulties and high costs associated with studies attempting to achieve and assess workplace change. However, it is also likely a result of an uncertain etiological picture; the most appropriate risk factors to be targeted may still be unknown or at least poorly understood. Because most etiological studies to date have rarely attempted to identify which specific components of work, among many, that might be contributing most to LBP incidence, the practical value of their findings may be limited. Knowing only that brick-layers may be at a relatively high risk of developing LBP, or that people who dislike their job may be more likely to report LBP, is of limited use in the development of effective interventions. Bricks still have to be laid, and workers still need to work, even if they don’t like their job. Research efforts that focus individual-level measurements on generalizable physical exposures, such as spinal loading or trunk postures, may provide better guidance in this area.

Uncertainty about the most important (and most modifiable) occupational risk
factors, combined with the difficulty of designing and executing effective interventions that can withstand scientific evaluation, makes the demonstration of the effectiveness of primary prevention of LBP a difficult challenge. Indeed, some researchers now appear to believe that efforts aimed at preventing new cases of LBP are in fact futile, and that programs aimed at preventing chronicity (secondary prevention) are more likely to be more cost-effective.\(^1\)\(^2\)\(^46\) The conceptual model of LBP underlying this viewpoint basically accepts the development of LBP as an unavoidable consequence of adult life that is largely unaffected by the nature of work.\(^66\)\(^67\) Accordingly, in this view, research should focus on ways and means of helping people cope with disability and remain at work, rather than trying to prevent the onset of LBP in the first place.

Other researchers, argue, as presented above, that there is considerable preventive potential for workplace interventions and that concomitant primary prevention, before onset, is an especially worthy goal not to be given up lightly.\(^45\)\(^51\) There is now some empirical evidence to support this position. The cost-effectiveness of the primary prevention of LBP has been demonstrated in at least three studies.\(^59\)\(^60\) However, further workplace-level interventions need to be attempted and properly evaluated before firm recommendations can be made. To help better develop these interventions, more information is required on the specific, remediable components of work that confer LBP risk, from etiological studies making detailed assessments of the biomechanical and psychosocial work loads. At the same time, these studies need to implicitly recognize, and take account in their design, the limitations of workplace-based research. Clarifying the role of biomechanical and psychosocial risk factors for LBP at work would therefore undoubtedly help in the development of more effective interventions to reduce the burden of illness attributable to LBP.
Bibliography - LITERATURE REVIEW


STUDY DESIGN FEATURES

Defining Features of the Study

The main purpose of this dissertation was to explore the relative importance of biomechanical and psychosocial risk factors in the etiology of occupational LBP. Given the comments in the literature review about the relatively recent emergence of psychosocial factors in the etiology of LBP, and the criticisms of the methods used to assess workplace biomechanical exposures in prior research, a new study was required that could effectively examine factors from both areas, and thereby increase the existing knowledge base. This study differs from prior research by combining direct, individual-level measurements of the physical demands of work with an extensive interview-assisted questionnaire focusing on the psychosocial work environment.

Consequently, the study described in this report has several defining features:

1) it used a case-control approach;
2) it was based in a single, large industrial site to maximize efficiency;
3) special emphasis was given to the comprehensiveness of the exposure assessments, particularly the direct measurement of the physical demands of work;
4) detailed clinical data were available to profile study population;
5) its focus was on identifying work-related biomechanical and psychosocial risk factors while controlling for individual characteristics;

Through collaboration with other researchers, these key design features were intended to contrast other LBP etiologic studies that are now under way or nearing completion, such as a prospective cohort study in Holland that enrols subjects from many different work sites, and a general population case-control study in Sweden.
that will attempt to model statistical interactions between self-reported biomechanical and psychosocial variables. Both of these studies have much less detail in their exposure assessments but have much larger sample sizes and considerably different basic study designs. Because of the very different cultural and industrial contexts of these studies and their tremendous expense, a concerted effort was made to ensure that they be specifically designed to complement, rather than duplicate one another. (See Appendix 4.1: Summary Table of Key Features of New LBP Studies.)

**Design Influences**

Occupational musculoskeletal disorders such as LBP present a special series of methodological challenges to epidemiologists because of the prevailing confusion and controversy about the origins of the pain and disability. Under a climate of mistrust and concern generated by the socioeconomic consequences of work-related LBP, it is necessary to earn the good faith and active cooperation of the workplace parties. The challenges and sensitivities unique to workplace research have had additional influence on the design and execution of the study over and above the usual epidemiologic standards that need to be considered. The result has been one of the most comprehensive and complex LBP research efforts ever attempted. No other study of work-related LBP has ever collected such detailed information for so many subjects on so many occupational exposures, particularly the physical demands of work.

Due to the complexity and scope of the study, and of the exposure assessments in particular, this study has been, by necessity, a truly interdisciplinary effort. Experts in the fields of biomechanical and psychosocial exposure assessment were directly involved - from helping to select the roster of variables to be examined and the instruments to be used, to conducting the workplace biomechanical assessments.
In addition to the variety in the backgrounds of the principal investigators, this study has also benefitted considerably from extensive collaboration with other Canadian colleagues, most notably from the Institut de Recherche en Santé et en Sécurité du Travail du Quebec (IRSST), as well as from experienced occupational health researchers involved in ongoing LBP studies in Scandinavia, Europe and the United States of America.

Why Do a Case-Control Study?
A case-control approach was adopted mainly for reasons of efficiency and cost, given the intensive and expensive nature of the risk factor assessments used. It is also the most appropriate design for conditions requiring comprehensive risk factor assessments, particularly when these assessments require the use of expensive and logistically difficult measurement tools. It is recognized that while case-control studies are typically more flexible than cohort studies with regards to measuring exposure, because of the smaller case-control sample size, cohort studies can also examine several exposures, provided these are easily and inexpensively measurable. This was not deemed to be the situation with regards to a study of LBP etiology.

This study specifically chose to use “state-of-the-art” technology to address perceived inadequacies in the assessment of biomechanical exposures in previous LBP research. Addressing the “unhelpful polemic” regarding the role of the physical demands of work could not be done with the use of error-prone group level measures, such as job title, or self-reported exposures. It was recognized from the outset that this commitment to obtaining the best possible measure of the physical demands of work would be an expensive procedure, and one that would effectively eliminate a prospective cohort design.

Cohort studies generally require baseline (and sometimes follow-up) measurement
of the exposures of interest for a much larger number of study participants, and generally collect this information on a smaller number of suspected risk factors.\textsuperscript{5} Although a cohort design generally provides greater protection from potential biases (especially recall and selection bias), it was not considered feasible for a study involving detailed biomechanical exposure assessments of risk factors for occupational LBP. There were two main reasons for this: (i) not enough was known about the etiology of LBP to know which of the many suspected risk factors would be best suited for use in a workplace cohort study; and (ii) not enough was known about how to accurately measure exposures of interest, which may change over time and are usually very expensive to measure directly, particularly the work-related biomechanical exposures. No existing data sets were available for a retrospective cohort study of LBP, since the type of detailed exposure data required are not routinely collected in Canadian industrial settings either for psychosocial or biomechanical exposures.

One of the additional objectives of the overall IWH study was to develop a practical, less expensive "kit bag" of valid but simplified measurement tools that could be used to monitor the key biomechanical exposures of relevance to low back pain in workplaces or for future large-scale epidemiological studies. In their present form, as used for this "gold standard" study, the assessment techniques are far too expensive for large-scale prospective cohort studies. It was therefore concluded that the most practical study design option would be the case-control approach described herein. This design was regarded as the most cost-effective, scientifically rigorous way to examine the complex multifactorial etiology for a condition like occupational low-back pain, where optimal risk factor measurements are still under development.
Study Setting

The site originally planned for the study, a large steel maker in Hamilton, was recruited in early 1992. By early 1993, after site-specific developmental and pilot work had been completed, the company was unable to continue its involvement in the study due to a serious retrenchment of the steel industry and a major downsizing of the steel mill workforce, the first in the company's history. After extensive discussions leading to approval from both General Motors of Canada Ltd. and the Canadian Auto Workers (CAW National Office and CAW Local 222), the General Motors vehicle assembly operation in Oshawa, 65 kilometres east of Toronto, was selected as the study site.

<table>
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<th>GM - Oshawa autoplex</th>
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<tr>
<td>• 65 km east of Toronto</td>
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<td>• total hourly-paid work force close to 12,000</td>
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<tr>
<td>• 3 Divisions:</td>
</tr>
<tr>
<td>Car Assembly (6,500)</td>
</tr>
<tr>
<td>Truck Assembly (3,500)</td>
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<tr>
<td>Fabrications (2,000)</td>
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<tr>
<td>not part of study base</td>
</tr>
<tr>
<td>accessible to study:</td>
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<tr>
<td>Feb '94 to Nov '94 - truck plant only</td>
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<tr>
<td>Nov '94 to Dec '95 - car and truck plants</td>
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<tr>
<td>Nursing stations - handle all WCB reports and most other work-site health problems</td>
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<td>(Truck plant = 1 station; Car plant = 4 stations)</td>
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Figure 4.1: The Study Setting
As Figure 4.1 shows, this site is a very large complex, employing approximately 12,000 hourly-paid employees in the production of cars, light trucks and parts. Only 10,000 of these workers were available for the study base. The parts fabrication plant did not participate in the study, since it was located at the opposite end of the city from the main complex where the other two plants were situated. The actual number of person-years of observation in the two plants was estimated to be 13,856 (based on 22 months of accrual from the truck plant, with an average population of 3702, and 13 months of accrual from the car plant, with an average population of 6,525).

Only the hourly-paid ("blue collar") workforce was eligible for the study. Salaried workers ("management") were excluded because of the clear distinction in the type of work they performed, as well as the different system in place for handling and tracking occupational health problems for the salaried workforce. They did not have to use the plant nursing stations for filing health-related insurance claims. The variety of work performed in the production of cars and trucks was much greater than anticipated. Eligible workers were involved in the direct production and quality control of vehicles, repair and maintenance of equipment, material handling, relief work, and general housekeeping.

At the time of the study the truck assembly plant was operating on a 24-hour three shift schedule, while the car assembly plant ran at two shifts only (day and evening). Apart from the overnight shift in the truck plant, most workers rotated between the day and evening shifts every two weeks. The entire complex shut down for two weeks each July and for a week in December, over Christmas. Except for occasional retirements and movement to other jobs within GM, the workforce was very stable over the nearly two years of study accrual. Very little new hiring occurred during this time frame.
The study site is the largest, single-site automobile manufacturing operation in the world. It had been extensively renovated in the late 1980's, so that it had a highly automated production system. Much of the production was completed using automated guided vehicles (AGV's) to bring the cars and trucks being manufactured to and from the different work stations. Some of the features of these AGV's are adjustable for the station workers, such as the working height of the vehicle under assembly. Robotics was used extensively in the production of the vehicles in these plants, especially for welding and windshield assembly.

A new vehicle came off each line approximately every two minutes, creating an extremely busy, and hectic environment in which to conduct a study. Interruptions to the production line because of the study were not tolerated, meaning that the job assessments performed in this study are truly reflective of the normal work being done at the complex. Participating workers required a substitute (often a group leader or "utility spare", as a substitute worker was referred to in this environment) to be available for approximately one hour, so that the study subject could be properly prepared and informed about the assessment of their job. The specific details about these assessments, and the interview used to collect the data on psychosocial work environment are presented in the following chapter.
Bibliography - DESIGN FEATURES


METHODS

This chapter describes: i) the type of subjects enrolled in the study and the methods used to enrol them; ii) the types of data that were collected from the study subjects and the methods used to collect these data; and iii) the types of analyses used to compare the study subjects and the methods used to perform these analyses. The chapter concludes with a discussion of ethical considerations.

Definitions of Study Subjects

All participants were drawn from the study base population consisting of approximately 12,000 hourly-paid, permanent full-time employees at the GM car and light truck assembly complex in Oshawa, Ontario. Participation was not restricted to “line workers” (those involved in the direct production of the vehicles). It was open to all “blue collar” workers, including maintenance workers, relief workers, the skilled trades, cleaners, production operators, line workers, material handlers, and team leaders.

Cases

The following inclusion criteria had to be met for an individual to be enrolled as a case:

i) pain, of the sprain/strain type, in the lumbar region of the back, between the bottom of the ribcage and the lower crease of the buttocks, reported to one of the nursing stations providing occupational health services to the study base;

ii) no previous nursing station report of LBP in the past 90 days;

iii) no LBP specifically attributed to fracture, current pregnancy, major congenital abnormalities, cancer, or infections;

Cases included workers with and without a Workers’ Compensation Board (WCB)
claim - i.e. filing a claim was not required for inclusion. There was no requirement for cases to be absent from work because of their LBP (i.e. to incur lost-time), nor did cases have to attribute the LBP to any specific event or injury at work. Subjects with pain radiating from the back down into the lower legs (possible sciatica) were not excluded (although no subjects with neurological deficits due to spinal nerve root impingement were enrolled). No medical exam was required to confirm the presence of LBP. Self-report of typical "mechanical" low-back pain to one of the on-site nursing stations was therefore the main entry requirement for the study.

Random Controls
The following condition was required to be enrolled as a control:

i) no previous nursing station report of LBP in the past 90 days.

Potential controls were not excluded from the study if responses to questions about their LBP history indicated that they may have had LBP but had not reported it to one of the nursing stations. Rather, these subjects formed a control sub-group referred to in the rest of the thesis as the "unreported LBP group". To be counted as a control with unreported chronic LBP, the person must have reported having had at least one episode of pain lasting one week or longer in the past year, or they must have reported having had 5 or more episodes lasting at least one day or longer in the past year. A control with unreported acute LBP was someone who reported having had pain in the last week, when they were interviewed. A "pain-free" control was therefore a subject who had not experienced either sort of back pain (acute or chronic).

Job-Matched Controls
This group of subjects are somewhat incidental to this thesis in that they are used only to provide data for the assessment of the biomechanical demands of the job
when such data for the case were not available. Eligibility criteria were the same as for the random controls, with the obvious exception that each subject must have been individually matched to one of the cases. This matching was intended to produce pairs of subjects with jobs that were virtually identical. As with the random controls, potential job-matched controls were not excluded from the study if responses to questions about their LBP history indicated that they may have had unreported LBP. However, since data on the job-matched controls were not used as a group in any analyses presented in this thesis, they were not further sub-divided by LBP status.

**Subject Accrual**

**Cases**

The procedure for selecting cases is outlined in Figure 5.1. Cases were accrued through the study site’s network of occupational health clinics. Due to restrictions regarding the confidentiality of workers’ medical information, it was not possible to directly monitor the nursing stations ourselves. Instead, the study relied upon the cooperation of the plant nursing staff to identify possible cases and obtain these patients’ permission for further contact by the study staff.

Daily telephone calls to the nurses at the stations allowed cases to be identified quickly, typically on the day of reporting. Log sheets were specially designed to permit estimation of the rate of refusals at the nursing station. Nurses asked only for permission to release the potential subject’s name and telephone number to the study team, who were responsible for explaining more fully the details of the study and for soliciting participation. Thus to minimize the efforts required of the busy occupational health nurses at GM, accrual was set up so that they functioned more as “gate-keepers” for the study, rather than as subject recruiters. This two-step accrual mechanism was determined to be the most efficient and systematic
procedure for finding relatively new cases of "occupationally significant" back pain in such a large and complex study setting. Finally, the WCB data for LBP claims during the study period was requested from the company, including descriptive data that would allow for assessing possible selection bias. (IWH has special access to WCB data through an information agreement with the Ontario WCB.)

![Case selection procedure diagram](image)

**Figure 5.1:** Case selection procedure.

**Random Controls**

The procedure for selecting the random controls is outlined in Figure 5.2. Entry into the study was made possible by being selected at random from a computerized roster of the full study base.
Any hourly-paid, full-time, permanent worker was eligible to be chosen as a random control. Since cases were collected through workplace reports of LBP without the requirement of any specific medical examination to confirm LBP, no medical tests were performed on the controls to exclude LBP. Indeed, the study was specifically designed to not exclude, from the control groups, workers who self-reported some form of LBP at the interview, so long as they had not sought out
treatment for it at one of the nursing stations in the previous 90 days.\(^a\)

A computerized roster of the employee numbers of all study base workers, without any identifying information, was obtained before the study began. The company numbers were numerically recoded using a consecutive sequence of numbers equal to the total number of employees on the roster, so that they could be easily retrieved using a random number generating program. Using the appropriate range of numbers, groups of 50 recoded employee numbers were selected using the random number generator available in the Quattro Pro spreadsheet program (Version 5.0, Borland International Inc., 1993). The computerized employee roster was updated four times over the course of the study to account for any staff turnover.

For reasons of confidentiality the study did not have direct access to the company’s employee information system, which contained the data needed to identify and contact potential subjects. Rather than obtain this information from the company’s liaison officer for the study each time a single case was accrued, the process was simplified by using batch selection of employee numbers. This avoided the need for a large number of separate random draws, each of which would have required a separate contact with the company personnel system. Therefore, each batch-processing job randomly generated the employee numbers of 50 potential controls. These employee numbers were passed back to the company who then provided the names and home and work telephone numbers of the potential subjects.

After being identified from the company personnel records, potential controls were sent letters indicating that they might be contacted by telephone in the near future

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\(^a\) As discussed later, a sub-group analysis of the controls was planned to assess the possible misclassification resulting from this design strategy. A previous study of LBP in an auto assembly plant in the US had shown the point prevalence of self-reported LBP to be about 50%. Excluding half the workforce from the study base could have had clear implications for the interpretation and utility of the findings of the present study.
about possible participation in the study. As each new case was identified, the next person in line, on the "short list" of potential controls who had not yet been contacted, was telephoned to solicit participation. If the worker refused, or was not contacted, the process was repeated until a subject was successfully recruited. People not at home when the study team phoned received up to ten attempted contacts. When all of the names on the short lists were exhausted, a new list of 50 potential controls was generated from the most recent study base roster.

**Job-Matched Controls**

Job-matched controls were selected from a list of workers performing the same job as the incident case. Normally this list was compiled by the biomechanical assessment team during the actual assessment of the case job. However, for cases who were known not to be getting an assessment because of refusal, a job change before they could be assessed, or extended disability, one of the assessment team leaders would make a special visit to the area where the case worked in order to identify potential matches. Where possible, these subjects were approached about study participation during this site visit.

For cases who did get an assessment, a special form (see Appendix 5.1) was left with their local area supervisor in the assembly plant when the assessment team studied the job. This form solicited the names of people doing the same job as the case. Where more than one name was submitted, one of these workers was randomly chosen as the job-matched control. Ideally, the control was chosen from the same shift as the case, since in some work areas, two parallel lines of vehicles were being assembled. If this was not possible, then the control came from one of the two alternating day/evening shifts. Where an exact job-match was not available, a compromise choice was made that was based on the observed physical demands of the job's tasks, as determined by the opinion of the biomechanical assessment team.
leader. Detailed *a priori* matching criteria were not feasible because of the extensive variety of jobs performed by the thousands of workers in the study base.

**Data Collection**

All subject management duties, including recruitment, booking interviews, data collection, storage and analysis, were the responsibility of the Institute for Work & Health research team, with the exception of the collection and preparation of the biomechanical assessment data, which was done in collaboration with the University of Waterloo occupational biomechanics laboratory.

There were two sources of data for the study: 1) the in-home interview (and physical exam) to assess health-related, individual and psychosocial variables; and 2) the detailed biomechanical assessments of each individual subject while at his/her usual job. Appendix 5.2 contains the full text of the study questionnaire, as used for the overall "IWH Integrated Study". Appendix 5.3(a) was provided by the expert biomechanists involved with the study. It contains a detailed description of each of the biomechanical measures used, as well as the background rationale for the approach.

1) **In-home Interview**

The study questionnaire was administered by a trained interviewer. Responses to each of the questions were recorded by the interviewer on a separate questionnaire while the subject read his/her own copy of the questionnaire. Interviews were booked immediately at the time of first contact with the subject, and completed in the worker's home, normally within one week of the his/her enrolment in the study.

The physical exam was administered by the non-clinician interviewers. It was
specifically designed to be simple and quick to administer, with the least amount of imposition for the subjects and the interviewers. The instruments used to collect the data were chosen on the basis of an exhaustive literature review and expert opinion (C. Bombardier, personal communication). They included a ruler, a hand grip strength device (a modified sphygmomanometer), a reflex hammer, and a wedge-shaped cushion placed under the subject's back to assist in the leg-raising and sit-up exercises.

It took approximately one hour to complete a typical interview and physical exam session. Subjects received a T-shirt and a study-logo-emblazoned coffee mug at the beginning of the interview to thank them for their participation. They were also left with a copy of a self-report questionnaire about the physical demands of their job, which was designed by the occupational biomechanics co-investigators. This questionnaire was to be returned directly to the assessment team, through the post. Its main use in relation to this thesis was in providing practical information about the subject's job that was used by the assessment team leader to help schedule and prepare for the actual job assessment.

2) Assessing the Biomechanical Demands of the Job

Collection of the biomechanical data was a very intense effort, requiring a team of at least two, and often three biomechanically-trained observers. The assessment was usually booked shortly after the in-home interview, where the subjects received the take-home physical demands questionnaire. Once this questionnaire was returned, and/or the basic description of the job tasks obtained from a short field observation where the questionnaire was unavailable, the worker and the worker's supervisor

\[\text{\footnotesize \textsuperscript{b}}\]

\textsuperscript{b} The collection of the biomechanical data used in this study was primarily the responsibility of the team of expert biomechanists from the University of Waterloo headed by Dr. Bob Norman and Dr. Richard Wells. They designed the biomechanical assessment procedures used and supervised the data collection. However, while the reduced set of biomechanical variables used in the final analysis of this thesis was chosen in collaboration with this expert team, the final variable choice for the statistical models reported later in this thesis was the sole responsibility of the author.
were contacted to arrange a mutually convenient assessment time during normal assembly line operation hours.

The biomechanical assessments were typically completed within one month of recruitment. There were three main reasons why additional time was required to get these assessments completed, compared to the one week needed to complete the in-home interview: i) the assessments were not booked until after the baseline interview was completed, so that unnecessary and expensive assessments would not be done on people who later withdrew from the study; ii) the assessments required some time away from work by the subject to set up and explain the assessment, thus agreement had to be obtained from the subject’s supervisor before the assessment could be done; and iii) logistical and communications problems within the two huge assembly plants often required the rescheduling of assessments.

Immediately prior to the collection of data, the study subjects met with the assessment team in one of several locations made available to the study personnel by the company. These offices provided the necessary privacy for preparing for the assessment equipment, fully explaining the assessment protocol to the subjects and obtaining their signed, informed consent. Subjects also had their height and weight recorded at this time. After the pre-assessment procedures were completed, subjects returned to their work stations and were observed for varying periods of time, ranging from two to four hours, with the amount of time required depending on the complexity of the job being assessed, and the ease and freedom with which the assessment team could conduct the study. The time period could not be standardized because of the wide variety of jobs and locations in the plants. Highly repetitive assembly line jobs could usually be studied within two hours (from start to finish, including preparation time). Non-routine jobs, such as those of maintenance workers, required a longer observation period to gauge the full range
of tasks they were required to do, with assessments often lasting up to four hours
for these workers.

To plan the biomechanical assessment, the team leader broke the subject's job down
into the core series of tasks required to do the usual work. The focus was on the
most frequently done tasks and the most demanding tasks that were required, with
emphasis placed on measuring the peak loads for the dynamic (working) and static
(waiting) components of these tasks. The time required to complete the tasks (cycle
time) was also recorded so that an estimate of cumulative exposure over the
observed shift could be generated. The work was videotaped for freeze-frame
computerized analysis of the posture and biomechanical model estimations of spinal
forces. Posture was also recorded by one of the team members using a check sheet
coded with a series of 13 pre-determined back postures at random sampling
intervals (10-15 seconds) over the assessment period. Force transducers were used
to measure the loads handled. The assessment team included someone to guide the
procedure and monitor the EMG back pack, as well as at least one other person, to
work the video camera (for postural and computer-assisted spinal loading analyses)
and manually record the posture using the pre-categorized sampling sheets. Loads
handled by the worker were also recorded, as were a few basic occupational
hygiene details about the work environment, such as ambient temperature and floor
surface. More complete details about the overall assessment procedures can be
found in Appendix 5.3(a).

Study Variables
This study examined a wide range of potential etiologic factors. The data collected
can be divided into four broad categories: health-related subject characteristics;
other individual characteristics; potential psychosocial risk factors; and potential
biomechanical risk factors. For each of these categories, the rationale for why these
data were collected is outlined. This is followed by a detailed description of the variables examined.

The questions used for collecting the thesis data were part of the baseline questionnaire from the IWH Integrated Study, found in Appendix 5.2. To make it easier for the reader to know which of the specific questions from the IWH questionnaire were used for this thesis, simplified versions of these questions have been pulled out of that larger questionnaire and placed in the body of text that follows.

Health-Related Characteristics

Rationale

The health-related data presented were collected for four main reasons:

1) to provide information on the severity of LBP amongst the cases;
2) to document the extent of unreported LBP among the controls, and allow for sub-group analysis based on this distinction;
3) to provide data about prior LBP history so that the possible confounding effect of this variable could be controlled for in the main logistic regression analysis;
4) to provide background information about the general health profile of the study subjects so that the main findings of the study could be more broadly interpreted.

Apart from prior back pain history, these data were not considered for inclusion in the risk factor analysis. Most of these health-related data related to clinical features of LBP and therefore were not included in any analysis seeking to identify risk factors for its occurrence.

Measuring Low-Back Pain

Worker self-reports of LBP to the worksite nursing stations were required for a subject to be eligible as a case. Since no medical exam was used to confirm the LBP
for the cases, or exclude it for the controls, additional self-reported information about LBP and its associated disability was collected from all subjects.

Severity

All subjects completed the Pain Grade developed by Von Korff et al. As shown in Table 5.1, the instrument assesses the subject's perceptions of current, worst and average pain intensity. It also inquires about the perceived level of interference from LBP, in relation to work, family life and daily activities.

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Have you had back pain in the last year?</td>
<td>YES  NO</td>
</tr>
<tr>
<td>2. In the past year, how bad was your worst back pain, where 0 is No Pain and 10 is pain As bad as it could be?</td>
<td></td>
</tr>
<tr>
<td>3. In the past year, on average, how intense was your back pain (that is, your usual pain at the times you were experiencing pain)? (same scale as #2)</td>
<td></td>
</tr>
<tr>
<td>4. About how many days in the last year have you been kept from your work because of back pain?</td>
<td>DAYS</td>
</tr>
<tr>
<td>5. In the past year, how much has back pain interfered with your daily activities rated on a 0-10 scale, where 0 is no interference and 10 is unable to carry on any activities?</td>
<td></td>
</tr>
<tr>
<td>6. In the past year, how much has back pain changed your ability to take part in recreational, social and family activities where 0 is no change and 10 is extreme change?</td>
<td></td>
</tr>
<tr>
<td>7. In the past year, how much has back pain changed your ability to work (including housework) where 0 is no change and 10 is extreme change?</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.1: Questions for the Von Korff Pain Grade.

Data from the three pain-intensity questions are combined into a Characteristic Pain Intensity score, using the mean of the three responses expressed on a 0-100 scale.
The three disability questions also use a 0-10 rating and are combined in the same way to give the Disability Score. A score of 0-29 gives 0 Disability Points, 30-49, 1 point, 50-69 2 points and 70 or more, 3 points. The number of disability days (the amount of time LBP prevents normal activities) is then converted to Disability Points as well with 0-6 days giving 0 points, 7-14 giving 1 point, 15-30 2 points, and more than 30 disability days resulting in 3 points. The points from both scores are then added together to derive the overall Disability Points. When combined with the Pain Intensity score, the result is the Pain grade, on a 0-IV scale as shown in Table 5.2 below:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Scores</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero (0)</td>
<td>0 on all levels</td>
<td>Completely pain-free</td>
</tr>
<tr>
<td>I</td>
<td>Pain Intensity score &lt; 50; &lt; 3 Disability points</td>
<td>Low disability - low intensity</td>
</tr>
<tr>
<td>II</td>
<td>Pain Intensity score ≥ 50; &lt; 3 Disability points</td>
<td>Low disability - high intensity</td>
</tr>
<tr>
<td>III</td>
<td>3-4 Disability points, regardless of Pain Intensity score</td>
<td>High disability - moderately limiting</td>
</tr>
<tr>
<td>IV</td>
<td>5-6 Disability points, regardless of Pain Intensity score</td>
<td>High disability - severely limiting</td>
</tr>
</tbody>
</table>

Table 5.2: Scoring System for the Von Korff Pain Grade

In addition to the Von Korff instrument, subjects were also asked about pain radiation from the back into the lower legs to document the extent of possible sciatic nerve involvement.

**Disability**

Disability from LBP was more directly assessed by a LBP-specific instrument developed by Roland and Morris. This is a 24-item questionnaire with each
positive response to one of the questions about common LBP-related disability problems contributing one point to the simple summary score ranging from 0-24. The questions from this instrument are shown in Table 5.3.

<table>
<thead>
<tr>
<th></th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I stay at home most of the time because of my back problem or leg pain (sciatica).</td>
</tr>
<tr>
<td>2</td>
<td>I change position frequently to try and get my back or leg comfortable.</td>
</tr>
<tr>
<td>3</td>
<td>I walk more slowly than usual because of my back problem or leg pain (sciatica).</td>
</tr>
<tr>
<td>4</td>
<td>Because of my back problem, I am not doing any of the jobs that I usually do around the house.</td>
</tr>
<tr>
<td>5</td>
<td>Because of my back problem, I use a handrail to get upstairs.</td>
</tr>
<tr>
<td>6</td>
<td>Because of my back problem, I lie down to rest most often.</td>
</tr>
<tr>
<td>7</td>
<td>Because of my back problem, I have to hold onto something to get out of an easy chair.</td>
</tr>
<tr>
<td>8</td>
<td>Because of my back, I try to get other people to do things for me.</td>
</tr>
<tr>
<td>9</td>
<td>I get dressed more slowly than usual because of my back problem or leg pain.</td>
</tr>
<tr>
<td>10</td>
<td>I only stand for short periods of time because of my back or leg pain.</td>
</tr>
<tr>
<td>11</td>
<td>Because of my back problem, I try not to bend or kneel down.</td>
</tr>
<tr>
<td>12</td>
<td>I find it difficult to turn over in bed because of my back problem or leg pain.</td>
</tr>
<tr>
<td>13</td>
<td>My back or leg is painful almost all the time.</td>
</tr>
<tr>
<td>14</td>
<td>I find it difficult to get out of a chair because of my back problem or leg pain (sciatica).</td>
</tr>
<tr>
<td>15</td>
<td>My appetite is not very good because of my back pain.</td>
</tr>
<tr>
<td>16</td>
<td>I have trouble putting on my socks (or stockings) because of my back problem or leg pain (sciatica).</td>
</tr>
<tr>
<td>17</td>
<td>I only walk short distances because of my back problem or leg pain (sciatica).</td>
</tr>
<tr>
<td>18</td>
<td>I sleep less well because of my back problem.</td>
</tr>
<tr>
<td>19</td>
<td>Because of my back pain, I get dressed with the help of someone else.</td>
</tr>
<tr>
<td>20</td>
<td>I sit down for most of the day because of my back.</td>
</tr>
<tr>
<td>21</td>
<td>I avoid heavy jobs around the house because of my back problem.</td>
</tr>
<tr>
<td>22</td>
<td>Because of my back problem I am irritable and bad tempered with people more than usual.</td>
</tr>
<tr>
<td>23</td>
<td>Because of my back problem, I go up stairs more slowly than usual.</td>
</tr>
<tr>
<td>24</td>
<td>I stay in bed most of the time because of my back problem or leg pain (sciatica)</td>
</tr>
</tbody>
</table>

Table 5.3. Component questions of the Roland back disability scale.

Prior LBP data

Other questions, shown in Table 5.4, addressed prior LBP, including surgery or hospitalization related to LBP, the number of prior lifetime episodes, and the
number of LBP episodes in the past year and the week prior to the interview. Subjects were also asked if any of their prior LBP episodes led to Workers' Compensation Board (WCB) claims.

<table>
<thead>
<tr>
<th>Question</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Have you ever been hospitalized for back surgery?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Other than back surgery, have you ever been hospitalized because of your back?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. a) In the past year, have you had an episode of back pain or leg pain that lasted at least one day?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) If YES, have any of these episodes lasted more than one week?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. In the past year, have you had 5 or more episodes that lasted more than one day?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. In your lifetime, how many episodes of back pain or leg pain (sciatica) have you had that lasted at least one day, but eventually went away completely?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Were any of these episodes a Workers' Compensation claim?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.4: Questions about prior LBP.

Other Health-Related Data
Three other sources of health-related information were used: 1) a comorbidity scale; 2) the SF-36, measuring overall health-related quality of life; and 3) a simple physical exam. All three measures were included so that a detailed picture of the
health profile of the study population could be generated.

*Comorbidity*

The comorbidity scale was developed specifically for the overall IWH study. As shown below in Table 5.5, it is a series of seventeen questions about the presence or absence of other common health problems. A positive response to each question added one point to the comorbidity scale, the simple sum of all “yes” responses.

<table>
<thead>
<tr>
<th>HEALTH CONDITION</th>
<th>DO YOU HAVE THIS CONDITION?</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTHMA/BRONCHITIS/EMPHYSEMA</td>
<td>YES</td>
</tr>
<tr>
<td>HIGH BLOOD PRESSURE</td>
<td></td>
</tr>
<tr>
<td>HEART TROUBLE/PACEMAKER</td>
<td></td>
</tr>
<tr>
<td>EFFECTS OF STROKE</td>
<td></td>
</tr>
<tr>
<td>TROUBLES WITH BALANCE</td>
<td></td>
</tr>
<tr>
<td>EPILEPSY</td>
<td></td>
</tr>
<tr>
<td>DEPRESSION/ANXIETY</td>
<td></td>
</tr>
<tr>
<td>DIABETES</td>
<td></td>
</tr>
<tr>
<td>VISION LOSS EVEN WITH GLASSES</td>
<td></td>
</tr>
<tr>
<td>HEARING LOSS</td>
<td></td>
</tr>
<tr>
<td>CHRONIC FOOT TROUBLE</td>
<td></td>
</tr>
<tr>
<td>KIDNEY TROUBLES/URINE INFECTION</td>
<td></td>
</tr>
<tr>
<td>STOMACH ULCERS</td>
<td></td>
</tr>
<tr>
<td>CANCER (OTHER THAN SKIN)</td>
<td></td>
</tr>
<tr>
<td>PSORIASIS</td>
<td></td>
</tr>
<tr>
<td>SKIN INFECTION</td>
<td></td>
</tr>
<tr>
<td>INTESTINAL DISORDERS</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.5: Questions about other health conditions.
Health-Related Quality of Life

The second instrument used was the SF-36, a 36 item questionnaire designed to measure health-related quality of life. Table 5.6 shows the components of the eight sub-scales assessing various aspects of physical, mental and general health as well as limitations in function and usual role.

<table>
<thead>
<tr>
<th>SF-36 sub-scales</th>
<th># of items</th>
<th>Concepts addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>I: Functional status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Physical functioning</td>
<td>10</td>
<td>vigorous and moderate activities, lifting, climbing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>stairs, bending, walking, bathing</td>
</tr>
<tr>
<td>b) Social functioning</td>
<td>2</td>
<td>interfered with or limited by physical health or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>emotional problems</td>
</tr>
<tr>
<td>c) Role limitations (physical)</td>
<td>4</td>
<td>reduce time at work or what was accomplished, limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>work activity, create difficulty with performing work</td>
</tr>
<tr>
<td>d) Role limitations (emotional)</td>
<td>3</td>
<td>reduce time at work or what was accomplished, limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>care taken when performing work</td>
</tr>
<tr>
<td>II: Wellbeing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Mental health</td>
<td>5</td>
<td>very nervous, could not be cheered up, calm, sad, happy</td>
</tr>
<tr>
<td>b) Energy and fatigue (vitality)</td>
<td>4</td>
<td>full of pep, lot of energy, worn out, tired</td>
</tr>
<tr>
<td>c) Bodily pain</td>
<td>2</td>
<td>severity, interference with normal work</td>
</tr>
<tr>
<td>III: Overall evaluation of health</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) General health perception</td>
<td>5</td>
<td>healthy as anyone, sick more often, expect health to</td>
</tr>
<tr>
<td></td>
<td></td>
<td>get worse, health is excellent, rating of overall health</td>
</tr>
</tbody>
</table>

(Note: only 35 questions were used to make scales; the remaining question comparing current health to that in past year, is not included. This table was adapted from Garret et al., 1993. The names for the scales as used in this report are in bold face)

Table 5.6: Components of the SF-36 Health-Related Quality of Life Instrument
The SF-36 is not specific to back pain. It is designed to capture aspects of health that are considered important to anyone, not just those with a specific condition. One of its main uses, and the reason it is included in this study, is to determine how much the general health of specific populations (such as study subgroups) deviates from what is expected for a general population of similar age and sex structure.\textsuperscript{4}

The response categories for the component questions varied from scale to scale, but the summary score is the simple algebraic sum of the component item responses in each case. (A detailed Manual and Interpretation Guide is available from the authors of the instrument.\textsuperscript{5}) To compare study groups, these scales can be standardized against values obtained from a reference population (e.g. US males aged 25-64), with the mean scores for the reference population set at zero and the difference between the expected (reference) scores and the study scores, expressed in standard deviations, used for relative comparisons.\textsuperscript{5} Although not shown in Table 5.6, summary mental health and physical health indices can also be generated from the items using weighted values of the standardized sub-scale scores. These two indices are expressed on a 0-100 scale. The specific questions used to create the various scales are found in the study questionnaire included in the Appendix 5.2.

\textit{Physical Exam}

Finally, a simple clinical exam was given to each study subject at the time of the interview. This exam, administered by the specially trained non-clinician interviewers, assessed six clinical endpoints believed to be of prognostic relevance: restricted range of motion (finger-to-floor distance); straight leg raising; sit-ups; hand grip strength; ankle, knee and hamstring reflexes; and tenderness (presence of specific tender points). The form used to collect these data is in Appendix 5.4.
Individual Characteristics

Rationale
In addition to being included as potential confounders, data about individual characteristics and health-related behaviours, as well as some specific aspects of the subjects’ employment, were collected to provide a thorough description of the study population. A list of these variables and the expected effect they might have on the reporting of LBP (i.e. the reason they were included in the study) are shown in Table 5.7 below.

| a) Individual characteristics |
|-------------------------------|----------------------------------|
| VARIABLE                      | EXPECTED DIRECTION OF EFFECT     |
| Age (years)                   | Age may increase risk (for acute LBP) or modify exposures |
| Height (m)                    | Taller people may be at higher risk of reporting LBP |
| Weight (kg)                   | Obese people may be at higher risk of reporting LBP |
| BMI (body mass index)         | Higher BMI may increase risk of reporting LBP |
| Gender                        | Some suggestion that males at higher risk of reporting LBP |
| Marital status                | Unmarried people are possibly at higher risk |
| Preschool children            | Having young children at home may increase risk (e.g. via lifting or stress) |
| Main wage earner              | Financial concerns may affect reporting of LBP |
| Alcohol consumption           | Higher consumption may increase risk of reporting LBP |
| Current smoker                | Smoking may increase risk of reporting LBP |
| Non-occupational activity *   | Increased level of sweat-inducing activities may affect risk |

| b) Employment characteristics |
|-------------------------------|----------------------------------|
| Shift work                    | Shiftwork may increase risk of reporting LBP or modify exposures |
| Apprenticeship                | Having an apprenticeship may modify exposures |
| Time at present job           | Lower experience may increase risk |
| Prior job change due to LBP * | Change may modify exposures |
| Commuting time (min) *        | Longer commuting time may increase risk of reporting LBP |

(* = variable obtained from the Waterloo Physical Demands Questionnaire.)

Table 5.7: List of Individual and Employment Factors Examined in the Study.

Variables
A typical population profile was generated, using data about age, gender, height, weight, (combined to form body mass index, as weight/height²), the highest
education level achieved, and marital status (dichotomized to married or other). The questions used for these descriptive variables are shown in Table 5.8. The questions about the age of children living in the home were used to create the "preschool children" variable shown in Table 5.7. Children of age 5 years and under were defined as "preschool".

1. Your sex: MALE FEMALE
2. What is your date of birth? _____/_____/19____
   DAY MONTH YEAR
3. What is your height?
4. What is your weight?
5. What is your marital status?
   NOW MARRIED OR LIVING COMMON LAW.
   SINGLE (NEVER MARRIED).
   WIDOW OR WIDOWER.
   SEPARATED OR DIVORCED.
6. (a) Do you have children living with you (either your own or from another relationship)?
   (b) If YES, how many children?
   (c) If YES, what are their ages?
7. Are you the main wage earner in your household?
8. Other than an apprenticeship, what is the highest level of education that you have completed?
   No Formal Schooling
   Some Primary School
   Primary School
   Some Secondary Or High School
   Completed Secondary Or High School
   Some Community College, Technical College, CEGEP, Or Nursing Program
   Completed Community College, Technical College, CEGEP, Or Nursing Program
   Some University (Not Completed)
   University Degree (Completed)

Table 5.8: Questions about individual characteristics.

The questions used to collect data on the prevalence of current cigarette smoking, alcohol consumption in the past year and the extent of usual non-occupational
physical activity are shown below. The assessment of non-occupational activities was based on the scale developed by Godin and Shephard. Data for this variable were obtained using the Waterloo Physical Demands Questionnaire found in Appendix 3(b).

<table>
<thead>
<tr>
<th>1. Do you smoke cigarettes?</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. In the past 12 months, have you taken an alcoholic drink?</td>
<td>Twice a day</td>
<td>Daily or Almost daily</td>
</tr>
<tr>
<td>or more</td>
<td>a week</td>
<td>a month</td>
</tr>
<tr>
<td>3. Considering a 7-day period (a week), how many times on the average do you do the following kinds of exercise for more than 15 minutes during your free time?</td>
<td>TIMES PER WEEK</td>
<td></td>
</tr>
<tr>
<td>a) STRENuous exercise (HEART BEATS RAPIDLY)</td>
<td>(examples: running; jogging; hockey; football; soccer; squash; basketball; cross country skiing; judo; roller skating; vigorous swimming; vigorous long distance hiking)</td>
<td></td>
</tr>
<tr>
<td>b) MODERATE EXERCISE (NOT EXHAUSTING)</td>
<td>(examples: fast walking; baseball; tennis; easy bicycling; volleyball; badminton; alpine skiing; popular and folk dancing; easy swimming)</td>
<td></td>
</tr>
<tr>
<td>c) MILD EXERCISE (MINIMAL EFFORT)</td>
<td>(examples: yoga; archery; fishing; bowling; horseshoes; golf; snowmobiling; easy walking)</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.9: Questions about health-related behaviours.

<table>
<thead>
<tr>
<th>1. Are you required to work shifts?</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Starting date of current job:</td>
<td>Month</td>
<td>Year</td>
</tr>
<tr>
<td>[Not starting date for G.M.]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Have you completed an apprenticeship program?</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>4. Did you ever permanently change jobs because you were having too much BACK PAIN?</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>5. On average, how long does it usually take you to get to work?</td>
<td>Less than 15 min</td>
<td>15-30 min</td>
</tr>
</tbody>
</table>

Table 5.10: Employment-related descriptive variables examined in the study.
The questions assessing general employment-related variables are shown in Table 5.10. The variables examined included whether or not subjects were required to work alternating daytime, evening or midnight shifts, how long they had been at their current job (not the time spent with GM), whether they had formal apprenticeship training, whether they had ever changed a job specifically because of LBP, and how long they usually took to get to work each day. Data for the last two variables were obtained using the Waterloo Physical Demands Questionnaire.

Subjects were also asked to state their job title. This information was recoded into a four-category variable used in the study setting. Production operators are people directly involved in the building of the vehicles. Support workers include material handlers, group leaders, and cleaners, while maintenance workers include most of the skilled trades, such as electricians and millwrights. Utility workers fill in for someone who is absent for the day, or they provide short term relief (breaks) to a group of several people (usually production operators). This four-category, site-specific job classification system was preferable to a standardized version (such as the Standard Occupational Classification, or SOC codes) because of the unique nature of the work being done at GM and the fact that the study was limited to a single industrial site. Since very detailed data were collected on the actual demands of the job for individual subjects, this job-category variable was not used in any of the risk factor analyses. The main use of these data was to better describe the study population for the study stakeholders. They also permitted an analysis of the validity of using such job categories as surrogates for the physical demands of work, a strategy used in other studies.

Psychosocial Factors

Rationale

The study questionnaire was compiled primarily to address the workplace
psychosocial environment. Along with the biomechanical factors described in the next section, data on the psychosocial work environment were collected as the primary risk factor variables. The list of the psychosocial variables examined in the study and their expected impact are shown below in Table 5.11.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>EXPECTED DIRECTION OF EFFECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psychological demands</td>
<td>Higher psychological demand thought to increase LBP risk</td>
</tr>
<tr>
<td>Job Control</td>
<td>Lower control over job content and activities thought to increase LBP risk</td>
</tr>
<tr>
<td>Supervisor social support</td>
<td>Poor relations with supervisor thought to increase reported LBP risk</td>
</tr>
<tr>
<td>Coworker social support</td>
<td>Poor relations with coworkers thought to increase reported LBP risk</td>
</tr>
<tr>
<td>Workplace social support</td>
<td>Poor work atmosphere may increase reported LBP risk</td>
</tr>
<tr>
<td>Perceived physical exertion</td>
<td>Perceptions of heavy physical demands of job may increase risk</td>
</tr>
<tr>
<td>Job self-identity</td>
<td>Poor sense of value and respect derived from work may increase risk</td>
</tr>
<tr>
<td>Job dissatisfaction</td>
<td>Increased dissatisfaction believed to increase reported LBP risk</td>
</tr>
</tbody>
</table>

Table 5.11: Psychosocial Variables Examined in the Primary Analysis.

Although the direct evidence in support of these factors having a causal role in LBP etiology was considered weak, there is some indication that psychosocial factors could play a role in the occurrence of LBP in the workplace. This is particularly true for variables assessing workers’ perceptions of the degree of control they have on the job and the psychological demands they experience at work, their perceptions about the degree of support available to them from supervisors and coworkers, their perceptions of the workplace social environment, feelings of a work-related identity, and job dissatisfaction. All except the last of these factors were assessed using a slightly modified version of the Karasek-Theorell Job Content Instrument (JCI).
Variables

The version of the JCI used in this study was based on the core format recommended by the instrument developers. This includes a total of 32 questions, including those from the original “Framingham” version, so named because of its use in the follow-up of the Framingham Heart Study cohort. Each of the 32 questions is in a four point Likert-type scale, with response options of either “Often, Sometimes, Rarely or Never” or “Strongly Agree, Agree, Disagree, Strongly Disagree”. The questions were combined together to make a total of seven subscales: 1) job control; 2) psychological job demands; 3) supervisor support; 4) coworker support; 5) workplace social environment; 6) physical exertion; 7) job self-identity. The components questions of these scales are shown in the series of tables that are shown below.

Component questions of the **Job Control** scale.

1. My job requires that I learn new things.
2. My job involves a lot of repetitive work.
3. My job requires me to be creative.
4. My job allows me to make a lot of decisions on my own.
5. My job requires a high level of skill.
6. On my job, I have freedom to decide how I do my work.
7. I get to do a variety of different things on my job.
8. I have a lot of say about what happens on my job.
9. I have an opportunity to develop my own special abilities.

Component questions of the **Psychological Demands** scale.

1. My job requires working very fast.
2. My job requires working very hard.
3. I am asked to do an excessive amount of work.
4. I have enough time to get the job done.
5. I am free from conflicting demands that others make.

Component questions of the **Supervisor Support** scale.

1. My supervisor cares about those under him/her.
2. My supervisor pays attention to what I am saying.
3. My supervisor is helpful in getting the job done.
4. My supervisor is successful in getting people to work together.
Component questions of the Coworker Support scale.
1. My fellow workers are understanding when I have a bad day.
2. My fellow workers are supportive.
3. My fellow workers take a personal interest in me.
4. My fellow workers are helpful in getting the job done.

Component questions of the Workplace Social Environment scale.
1. There is a pleasant atmosphere at my workplace.
2. I feel I am harassed at work because of my race or sex.
3. There are frequent conflicts at my worksite.
4. There is nobody at work I can talk to about job problems.

Component questions of the Physical Exertion scale.
1. My job requires lots of physical effort.
2. My work requires rapid and continuous physical activity.

Component questions of the Job Self-Identity scale.
1. I am appropriately respected and rewarded by my company for my work.
2. My skills and abilities are "vital" to my work group or unit.
3. I feel my immediate supervisor considers my job very important.
4. My fellow workers consider my job very important.

The study questionnaire addressed workers' feelings on job satisfaction using questions from two major occupational cohort studies, the Boeing study of LBP and the Whitehall study of the British civil service. These questions, shown below, were combined together, using the simple sum of the scores from the two questions, to give a summary Job Dissatisfaction score.

Component questions of the Job Dissatisfaction scale.
1. I enjoy the tasks involved in my job.
2. About your job in general - how satisfied are you with your job as a whole taking everything into consideration?
In addition to the JCI physical exertion scale, the study questionnaire also included the Borg Scale, to assess subjects' perceptions of the physical demands of work.\textsuperscript{11} The difference between this instrument and the JCI scale is the Borg Scale's specific focus on a self-rating of how the physical demands of the job affect the body.

The Borg Scale (Perceived Physical Demands).

How physically demanding on your body is your job?

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>very, very light</td>
</tr>
<tr>
<td>1</td>
<td>very light</td>
</tr>
<tr>
<td>2</td>
<td>usually light</td>
</tr>
<tr>
<td>3</td>
<td>a bit demanding</td>
</tr>
<tr>
<td>4</td>
<td>demanding</td>
</tr>
<tr>
<td>5</td>
<td>very demanding</td>
</tr>
<tr>
<td>6</td>
<td>very, very demanding</td>
</tr>
</tbody>
</table>

The last work-related variable to be examined was a measure of worker empowerment, adapted from a scale developed by Jencks.\textsuperscript{12} In contrast to the JCI job control scale, it focused on assessing perceptions about the workplace in general, as well as the workers' own job. The questions used are shown below.

Component questions of the Empowerment scale.

1. Do you need permission or do you have to find someone to take your place if you leave your work area for five or ten minutes?
2. How much do workers take part in decision making in the workplace?
3. I feel employees ideas/opinions are listened to by management.
4. I can influence the way work is organised in my work area.
5. I have control over how my work area is set up. (e.g. I can change the height of my chair, alter positioning of equipment, vary my bench heights, etc.)

The other variables included in the main risk factor analysis for the psychosocial
variables addressed factors less directly related to work, such as the occurrence of major life events in the past year, and perceptions of the subjects' education level compared to that of their coworkers performing similar jobs. The questions used to address these concepts are shown below.

Component question of the **Over-Education** variable.

Compared to other people in jobs like mine, my level of education (school, college, etc.) is:
- Much Higher
- Higher
- About the same
- Lower
- Much lower

Component question of the **Major Life Events** variable.

In the last 2 years have you had any deeply troubling personal experiences or severe stress (e.g., loss of a loved one, serious marital, financial, or legal problems, robberies, etc.)?

Finally, Pearlin's mastery scale, addressing the subjects' perceptions of locus of control (also called coping or mastery) was also included. This psychological scale was included because of a belief that workers' ability to adjust to difficult situations, such as the presence of LBP, might affect their likelihood of reporting it to the worksite. The variable included in the final analysis was created by summing the responses to a series of 7 questions about how much control one has over life events. These component questions of the mastery scale are shown below.

Component questions of **Pearlin's mastery** scale.

1. I have little control over the things that happen to me.
2. There is really no way I can solve some of the problems I have.
3. There is little I can do to change many of the important things in my life.
4. I often feel helpless in dealing with the problems of life.
5. Sometimes I feel that I'm being pushed around in life.
6. What happens to me in the future mostly depends on me.
7. I can do just about anything I really set my mind to do.

**Data Handling**

Because all responses to questions were transcribed directly onto the questionnaire by the interviewer, non-response was not a problem for the questionnaire variables used in the main analysis. There were few missing data or obvious coding or
transcription errors evident in the data set. The questionnaires were double-entered by different operators and the responses automatically cross-checked against each other, when double-entered, to ensure a high level of data quality. The data from the questionnaires were entered using the Validata data entry program developed by the Institute for Work & Health.¹⁴

Composite variables from the Job Content Instrument (JCI), the principal psychosocial instrument used, were created according to the JCI User’s Guide.⁹ In all cases the scoring was a simple sum of the component questions that took into account the response direction. The one exception was the job control variable, which can be expressed as two separate sub-scales - decision authority and skill discretion. As prescribed by the authors, these are given equal weighting in the final job control scale (also called the “decision latitude” scale) even though there are only half as many questions used to form the decision authority sub-scale.

To avoid losing information already collected, these terms were left in their discrete (raw) form as a sum of questionnaire scores, rather than converted to their more conventional dichotomous or tertile formats.

**Biomechanical Factors**

**Rationale**

The assessment of the job demands was specifically designed to provide information about the generic components of work believed to be important in the development of LBP. This focus on generic variables such as estimates of biomechanical forces, rather than recording the number or type of specific tasks performed in the assembly complex, was intentional, since it was believed the results would be more widely applicable outside of the automotive context. Also, the speed at which technological change occurs in modern automobile production facilities means that
specific tasks performed today may be gone by the time a study is completed and analysed. Focusing on factors that were not task-dependent meant that the findings would be more likely to be of relevance for future primary prevention efforts outside the study site, as well as within it.

Variables
The breadth and complexity of the biomechanical variables examined in this study were meant to provide a detailed picture of the physical loads that workers handled, the forces that they experienced in their lower back in response to the demands of their jobs, and the postures they adopted to perform their jobs. The list of factors that were included in the final analysis, as well as a brief description of what each was intended to measure, is shown below in Table 5.12. All were expected to increase the risk of LBP at higher exposure levels, based on biomechanical theory and previous studies. The table is divided into three parts according to how the variables were derived or measured.

In general terms, the model used was a two-dimensional quasi-dynamic model (WATBAK) developed by the University of Waterloo biomechanics team.\textsuperscript{15,16} Asymmetric body positions could be accounted for, as well as the magnitude and direction of forces acting on the hands, and the position of this force relative to the subject's body. Height, weight and gender were also required inputs for the model, which were used in conjunction with published population norms for assumptions of leverage points in the model. Specific details about the assumptions of the biomechanical model, used to derive the estimates of compression and shear forces in the study analyses, are beyond the scope of this thesis. They are explained in more detail in the co-authored paper nominated for the 1997 International Society of Biomechanics Clinical Biomechanics Award, found in the Appendix.
a) Computer Model Analysis of Measured Loads and Video-taped Postures

- Peak Disc Compression: Highest vertical crush force on the lumbar spine intervertebral discs
- Integrated Compression: Estimate of disc compression for typical shift (task, static and waiting data)
- Low Loading: Estimates of lumbar disc compression from low-level static loading
- Peak Shear: Highest estimate of reaction force acting perpendicular to spinal column

b) Posture-related Variables from Video Analysis (no external load used to derive estimates)

- Awkward Posture Index: Time-weighted analysis of any trunk posture more than 20 degrees from neutral
- Peak Extensor Velocity: Maximum speed recorded from posture analysis for upward trunk motion
- Peak Flexor Velocity: Maximum speed recorded from posture analysis for downward trunk motion
- Peak Flexion: Largest absolute trunk angle recorded

c) Variables Based on Field Recorded Data or Observations

- Average Disc Compression: Time-weighted (random) sample of observed postures and loads
- Peak Hand Force: Largest force observed during dynamic or static activity
- Number of back moves: Average number of observed back moves per minute (in sagittal plane)

Table 5.12: Biomechanical Variables Examined in the Primary Analysis.

Biomechanical Data Reduction

After each assessment was completed, the University of Waterloo data collection team leader went through the subject’s file to ensure that all data collection procedures had been properly complied with. Errors and omissions were noted in the file to prevent the reduction and use of inaccurate data. This review was also used to identify the video and EMG clips of the relevant peak loading tasks used for the computation of spinal force estimates, such as peak shear.

The reduction of the biomechanical data into a form appropriate for the final epidemiological analysis was an enormous task, requiring hundreds of skilled person-hours of work. Because of the variety of methods used by the common metric assessment approach, each subject’s data-file required approximately ten
hours of data reduction for each hour of field observation. With assistance from the author, a final thorough review of the reduced data from each subject's file was performed by the University of Waterloo researchers, before it was released to the author for the main analysis. The purpose of this final review was to identify, and where possible rectify, problems with transcription errors, missing data, values that were clearly out of acceptable ranges, or outlying values that required further checking.

Because of the extensive nature of the data collection for biomechanical variables, this thesis used only a predetermined and narrowly defined subset of the available data for the main risk factor analysis by unconditional logistic regression. Before data collection was started, a list of "a priori" most promising variables intended for use in the main risk factor analysis was drawn up in collaboration with the expert biomechanical team from the University of Waterloo. This process resulted in a list of approximately 25 variables. Further reduction of the number of variables examined in the final analysis was necessitated because of technical problems with: i) the electromyography (EMG) instruments, that reduced the number of subjects with available data on the peak moment variable to critically low numbers; and ii) the method used to determine peak extension that produced values outside acceptable biomechanical limits because some supported postures (workers sat in chairs) were inadvertently included, leading to trunk extensions above 10 degrees.

As a result, all EMG-derived moment variables were excluded from the final analysis, as was peak extension.

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c The full "raw" data set collected by the Waterloo team contains several hundred variables, due to the planned comparison of several different data collection techniques and the composite nature of several of the measures used.

d All biomechanical variables derived from the University of Waterloo Physical Demands Questionnaire were also withdrawn from the thesis analysis due to a combination of low response for this self-administered instrument as well as concerns about the quality of these data. There was a very high level of missing data, possibly because many subjects became frustrated by the comprehensive, task-oriented nature of this self-administered instrument designed by the biomechanical investigation team.
The preferred list of biomechanical variables was further shortened by creating an index term from the available posture variables. The proportions of time spent in all mutually exclusive postures above 20 degrees from neutral were added together to yield a single, summary term of time in awkward (i.e. non-neutral) postures. Use of this index helped reduce the number of factors included in the analysis and made the results more directly comparable to those of a seminal case-control study by Punnett et al.17

Study Comparisons

Figure 5.3 shows the comparisons originally planned for the thesis. The primary comparison (#1), to identify the main work-related risk factors for LBP, involves the cases and the randomly chosen controls. This was the comparison used to derive the final multivariable statistical model described later in this report.

Figure 5.3: Study Comparisons.
Two additional sub-group contrasts were attempted: both were intended to serve as sensitivity-type analyses for the main results by providing insight into the possibility of information bias and/or misclassification error affecting the results. Because their main purpose was to gauge the sensitivity of the main findings to measurement error in the job assessment data and misclassification error, from unreported pain among the controls, these sub-analyses were performed only after the final regression model had already been produced from the main comparison.

The first sub-group comparison (#2) stratifies the cases by use or non-use of "proxy" biomechanical information (i.e. when a case could not get the physical demands of his/her job assessed he or she was assigned the biomechanical risk factor data from the assessment of the job-matched control).

The second sub-group comparison (#3) looks at the impact of including controls with unreported LBP (who as noted earlier, were not excluded unless they had reported LBP to the nursing station in the previous three months). The point of this analysis was to determine if these subjects with unreported pain were so similar to cases that the study was at risk of "false negative" results due to extensive misclassification. The rationale for each of these comparisons is outlined below.

**Main Comparison**
Unmatched, randomly chosen controls were used as the main comparison group for the cases.

**Required Sample Size**
The sample size chosen was a compromise that was influenced by three main factors:

1) the power of the study to address its main objective of LBP risk factor identification;
2) the time required to accrue eligible study participants (i.e. the potential to complete field work and data reduction in a reasonable period of time); and 3) the high costs incurred for each person enrolled in the study, due mainly to the nature of the biomechanical assessments used.

Obtaining data on which to base pre-study power calculations was difficult, since no other study had performed such a comprehensive set of exposure measurements, particularly with regard to the large array of individual-level biomechanical assessments that were planned for this study. Consequently, it was difficult to accurately determine the expected proportion of controls to be exposed to the main biomechanical study variables, or to estimate the excess risks these exposures would lead to in the study population. Information on the level of measurement error that could be expected for the biomechanical exposures was similarly lacking, although the general dilution effect on the risk estimates to be observed was understood (i.e. reduction in power).

Sample size estimates based on parameters from psychosocial exposures, such as job control and job demand, are also difficult to reliably estimate, given the paucity of high-quality studies in this area. Therefore, basic sample size estimates (number of cases for a 1:1 case-control ratio) using several different values of risk and exposure were generated. These are shown in Table 5.13.18

<table>
<thead>
<tr>
<th>RR</th>
<th>0.10</th>
<th>0.30</th>
<th>0.50</th>
<th>0.70</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>763</td>
<td>356</td>
<td>325</td>
<td>419</td>
</tr>
<tr>
<td>2.0</td>
<td>246</td>
<td>123</td>
<td>119</td>
<td>162</td>
</tr>
<tr>
<td>3.0</td>
<td>91</td>
<td>50</td>
<td>53</td>
<td>78</td>
</tr>
<tr>
<td>5.0</td>
<td>39</td>
<td>25</td>
<td>29</td>
<td>46</td>
</tr>
</tbody>
</table>

Table 5.13: Sample Size Estimates for Various Risk and Exposure Levels18
From the numbers found in Table 5.13 it was expected that the planned sample size of 150 cases and 150 controls would provide sufficient power to detect risk factors with odds ratios (OR's) of at least 2 and possibly lower, as long as the proportion of controls exposed ($p$) was not too extreme (i.e. $p \leq 0.25$ or $p \geq 0.75$). Extensive discussions with international collaborators and experts suggested that, if such an expensive study, with so many high quality measurements, could not find OR > 2, then other investigators and potential stakeholders would be unlikely to pursue such an investigative approach further.

Sample size estimates for the sub-group comparisons described below are not provided as these analyses are supplemental to the main analysis, and no specific hypotheses are being tested. Rather they were intended to broaden the understanding of the study's main findings.

**Sub-Group Comparisons**

a) Proxy Biomechanical Data

In circumstances where it was not possible to obtain direct biomechanical measures for cases, subjects were assigned the values obtained from the biomechanical assessment of their job-matched control. In addition to the sensitivity-type analysis mentioned above, the propriety of using the proxy data was assessed by contrasting these biomechanical variables for the 38 matched sets of cases and controls with complete data.

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* Based on accrual that was slower than expected, the full sample size of 150 cases could not be accrued by the end of calendar year 1995, when data collection had to cease for funding reasons. To maintain the projected study power, additional random controls were selected at an even rate during the last quarter of accrual, to offset the reduction in the case numbers. The number of additional controls sampled was limited by the ability of the biomechanical assessment team to handle the extra work. Priority was given to case assessments or the assessment of the matched control when cases could not be assessed.
b) Unreported LBP in the Random Controls

Since sampling of the unmatched controls was done at random and not driven by LBP status, the exact size of the "pain-free" sub-group could not be pre-determined. Rather, it was dependent on the prevalence of unreported pain in the workforce. As previously defined, the LBP-free sub-group consisted of people with no recent or chronic history of low-back problems. Comparing this sub-group of LBP-free controls to the LBP cases was intended to determine the extent, if any, of misclassification based on outcome (LBP). If the controls with unreported LBP had similar exposure profiles to cases, their inclusion in the control group may have diluted the study power. Thus, if the subjects with unreported LBP among the controls and the subjects with reported LBP among the cases have the same risk factors (i.e. they are of equivalent etiology) then removing controls with unreported LBP from the analysis should result in an increase in the OR estimates compared to those observed for the full sample.

Analytic Methods

The analysis was done in four stages: I) a description of subject accrual; II) an initial descriptive and exploratory phase of the clinical and individual characteristics of the cases and controls; III) the main risk factor analysis; and IV) the supplemental analyses that examined the effects of proxy data and unreported LBP in the controls on the study’s main findings. All computerized analyses were performed using the SAS System.19,20

Stage I: Accrual

Before performing the main analysis, the study accrual was summarized, including calculations of the proportion of eligible subjects agreeing to participate and the proportion of subjects with full data. Since the study did not have direct access to the subjects reporting LBP to the clinics or to their files, the total number of LBP
reports to the nursing stations could not be determined. Attempts at having the nurses keep track of unrecruited subjects were not successful.

Although the actual number of LBP reports to the nursing stations could not be determined, it was possible to get some idea of the approximate flow rate into the study using the WCB data for LBP claims provided by the company. Despite more extensive requests, identifying information, but no other claims-related data could be provided by the company thus a detailed look at possible selection bias based on data for WCB claimants was not feasible. The names on the company WCB list were cross-referenced to the names in the study data base to determine the study “capture” of WCB claimants. Unfortunately, the limited information available on the company WCB data set did not permit any further analysis to better refine the “true” capture number, which may be a severe underestimate. The company WCB files included many people who were likely ineligible for the study, as their claims could have been outside the study time frame or they may not have been part of the study base. Basic descriptive data, for the LBP claimants deemed potentially eligible, were obtained from the provincial WCB database in order to examine possible selection bias between recruited and unrecruited subjects.f

Stage II: Descriptive Analyses

The main purpose of the descriptive phase of the analysis was to provide a clear context for the study setting to assist readers in interpreting the results. Using only means and/or frequencies, cases and random controls were compared on a number of demographic and clinical variables to provide a thorough description of the subjects in the two groups involved in the main risk factor analysis. Special emphasis was given to the description of the clinical data, especially the LBP data, since no medical exam was used to confirm the LBP. The objective in providing so

f The IWH has a legal agreement with the Ontario WCB giving it access to the WCB claims database for research purposes.
much detail on the study subjects was to ensure that the generalizability of the results could be more readily assessed outside the study setting.

**Stage III: The Main Risk Factor Analysis**
The purpose of the main analysis was to answer the primary research question, regarding the identification and quantification of independent biomechanical and psychosocial risk factors for occupational LBP. This analysis was completed in three parts:

A) bivariable analysis of each risk factor to compare group mean values and to generate preliminary odds ratio (OR) estimates;
B) Separate correlation matrices and multivariable regression models within the biomechanical and psychosocial risk factor groups where required;
C) multivariable analyses to control for confounding and to give adjusted estimates of the independent effects for each of the main putative risk factors.

**Scaling the Odds Ratios**
Since all risk factors were examined in continuously scaled formats, logistic regression odds ratio estimates were produced using the interquartile range for the random controls as the benchmark exposure difference of interest.\(^{21}\)

**Correlation Matrices**
In addition to close monitoring of the behaviour of each of the terms during model building, Pearson correlation matrices were generated to inform the regression process. These correlation data were used to help interpret the effects seen on regression coefficients as variables moved in and out of the different models. They were also helpful in data reduction. If variables are correlated at very high levels (above 0.80) then a regression model including both factors could be unstable.\(^{22}\) When such correlations occurred, the variable with the strongest bivariable OR
estimate was retained for the multivariable model building process.

Regression Methods

While bivariable analysis can be a useful way to get familiar with the data set and identify potentially important risk factors, it does not account for the complex inter-relationships that likely exist in conditions with multifactorial causation. Identification of these independent risk factors, as well as the inter-relationships that exist between them, is made possible by multiple logistic regression. Since these multiple methods can adjust for the effect of several factors at a time, they can also provide an estimate of the combined risk workers would have if they were exposed to more than one risk factor. The mathematical model underlying multiple logistic regression implies not only that these risks are independent, but that the odds ratios used to estimate them are multiplicative, and thus can be used to evaluate risk for different combinations of exposures.\(^8\)

The multivariable analysis used a confounder approach with backwards stepwise multiple logistic regression to identify risk factors with the strongest independent effects.\(^{23}\) In backwards stepwise regression, the relative "ability" of each of the terms to account for case-control differences is first examined in the largest, most comprehensive statistical model, containing all of the variables deemed relevant. Once this "full" model has been examined, the variable that contributes the least amount of information is removed and the results of the now reduced model re-examined. Using the confounder approach to get to the final model meant that variables that showed no statistically independent effects were selectively removed as long as they did not influence the risk estimates for the remaining statistically significant terms by more than 10%. The stepwise model building process was

\(^8\) The study was not designed to test for formal interactions. A decision was made \textit{a priori} that no interaction terms would be added to the model because of the large number of variables already being examined, the inadequate power such analyses would likely have, and the lack of any clear criteria on which to base the formation of the interaction terms.
ceased when variables could no longer be removed without this condition failing.

Backwards regression was chosen because it does not depend as much on an arbitrary cut-off for inclusion in the statistical model as forwards regression methods that begin with a smaller model and add new variables. In this latter technique, variables must demonstrate a bivariable association of at least \( p < 0.25 \), or more often \( p < 0.10 \), before they are entered into the model.\(^{21}\) Critics of forward regression modelling point out that potentially important interrelationships among variables can be ignored if screening the bivariable associations based on an arbitrary statistical cut-off prevents any "negatively confounded" variables with significant multiple regression effects from ever entering the model.\(^{24}\) This could unnecessarily restrict the scope of the risk factors being examined. Careful monitoring of the effects on the remaining model terms as each variable was dropped, together with information from a separate regression model restricted to the biomechanical variables, and correlation matrices was combined to arrive at the final model presented below. This synthesis of information was able to identify the most important risk factors from a large starting model, and, while not a formal statistical analysis of interaction, it was also able to indicate possible interrelationships between study variables that remained in the final model, and others that were "forced" out.

**Goodness-of-fit and Model Adequacy**

Formal diagnostic checks of goodness-of-fit and model adequacy were also undertaken at each step. The statistics generated for this analysis included the Hosmer-Lemeshow goodness of fit statistic (H/L), the generalized coefficient of determination statistic, \( r^2 \), and the \( c \) statistic, the area under the receiver operating curve (ROC).\(^{20}\)
The H/L goodness-of-fit statistic measures how well the logistic model fits the data by comparing the expected and observed numbers of subjects found in a predetermined number of groups usually based on the deciles of expected outcome probabilities. Values of the H/L chi square statistic with a p-value below 0.10 indicate that the data were not well explained using logistic regression.

In addition to the H/L statistic, the quality of regression model could also be estimated from the adjustment to the generalized coefficient of determination statistic (or the r-squared statistic) as proposed by Nagelkerke. Like the typical multiple correlation coefficient, the intent of this statistic is to provide an indication of the ability of the model to "explain" or account for differences observed between cases and controls.

Although this study was not intended to generate predictive models for LBP based on risk factors, the estimate of the predictive power of the final model was measured by the c statistic, the area under the receiver operating curve (ROC).

**Regression Diagnostics**

Since the sample size for this study was not large by epidemiologic standards for case-control studies, it was important to determine if these data from only a few subjects could be exerting any disproportional influence on the final results. Typical regression diagnostic tools provide estimates of the influence of ill-fitting values in a number of ways, although they generally identify values that do not fit the derived model well. In other words, they focus on data-points that, if excluded, would improve the regression fit based on the type of statistics described above.

For the final multivariable model, the diagnostic statistics from the logistic regression computer program (PROC LOGISTIC) available from the SAS Institute
were examined. These included plots of Pearson chi square and deviance residuals to identify observations not well explained by the model; a hat matrix diagonal to detect extreme points in the design space; a Dfbeta diagnostic used to detect data points with extreme influence by examining the standardized difference in parameter estimates after deleting each of the observations used; C and CBAR, which are confidence interval displacement diagnostics also used to identify influential observations; and plots of DIFDEV and DIFCHISQ, which are changes in the deviance and the Pearson chi-square statistics respectively, when an individual observation is deleted (used to detect disagreement between the data and predicted values of the fitted model).

**Multiple Comparisons**

To limit the chance of missing potentially important associations by arbitrarily adopting an overly conservative statistical cut-point (type II error), no multiple comparison-type adjustments were made to the statistical significance level used. It was set at $\alpha=0.05$ for all comparisons. The total number of statistical comparisons was reduced by not prescreening the variables for inclusion in the starting logistic models used in the main risk factor analysis.

**Stage IV: The Supplemental Analyses**

a) Use of Proxy Biomechanical Data

The analysis included the calculation of intraclass correlation coefficients (ICC) to assess the level of agreement between the cases and their job-matched controls on several key study variables. The ICC calculations used in the analysis assumed the data to be series of pairs of repeated measures on the same subject, thus a 1:1 type of ICC was calculated. To determine the 95% confidence intervals, the short form calculation proposed by Krebs was used. Plots of case versus job-matched control data were made to visually verify the information obtained from the ICC
calculations, in conjunction with paired t-tests.

For the sensitivity-type analysis, cases using proxy biomechanical data were removed from the database and the final multivariable statistical model from the risk factor analysis was rerun, to determine if employing the proxy data strategy had any strong influence on the study findings.

b) Misclassification from Unreported LBP in the Controls
As described under the “Study Subjects”, unreported LBP was operationalized in two different ways: chronic LBP which was either an episode of pain in the past year that lasted for at least one week or 5 or more episodes of LBP of at least one day in duration in the past year. Acute LBP was defined as having had LBP in the week prior to the study interview. (These two definitions were used because of the difficulty in precisely defining “unreported” LBP.) The final multivariable statistical model from the risk factor analysis was rerun twice - once with the controls with chronic LBP removed from the data set, and once with the controls meeting the acute LBP definition removed.

Ethical Considerations
The study dealt with a number of sensitive issues, particularly: i) the confidentiality of solicited information, including personal data on the individual, his/her injury and views about the workplace; ii) on-site videotaping of employees performing their tasks; iii) possible difficulties for subjects with LBP during the pre-assessment calibration procedures required for the biomechanical assessments; and iv) identifying workers doing jobs that appear to carry excessive LBP risk, according to currently published evidence and ergonomic guidelines. All of these issues were carefully considered in the design of the study, and accommodations made as appropriate. For example, participants were not required to perform maximum
voluntary contractions for calibrating the instruments used to measure muscle activity of the back, as this was considered inappropriate for a work-place study. Approval of the IW&H Integrated Study of Occupational Soft Tissue Sprains and Strains was granted by the University of Toronto and University of Waterloo ethical review committees. Informed, written consent was obtained from each participant. The consent forms used for the study are attached in Appendix 5.5.

As discussed previously, under the section on Data Collection and Measurement Instruments, the management and union at General Motors (Oshawa) jointly decided that a summary information sheet about the biomechanical analysis of each job, known as the Physical Loading Report, or “PLR”, should be released to the participant, the union and the company within one month of the assessment being completed by the Waterloo team. This brief report was not a summary of the analysis of data on the detailed task-specific risk factors as presented in this thesis. Rather, it was an ergonomic “best practice” job demands analysis that was based on guidelines current at the time of initiating the study.

One of the main challenges of this procedure was to make the report accurate while keeping it comprehensible for people without biomechanical training. The report had to reflect what the job demands were, based on the existing guidelines, and it had to do it without unnecessarily alarming anyone in a delicate labour-relations environment. The process for this feedback had been carefully worked out between the workplace parties and the study team before data collection began. A colour-coded flagging system was devised that would identify as “red” those jobs found to have potentially harmful exposures, and “green” all others not so designated. This preliminary feedback process recommended that red-flagged jobs be the subject of further examination. The ranking system used was based on expert opinion of the University of Waterloo team, according to their synthesis of the available body of
biomechanical knowledge and the published physical loading guidelines in use at the time the study commenced. A copy of the PLR is found in Appendix 5.3(e).

Participants were informed before the biomechanical assessment that their names would be on these reports, and that these would be circulated to the company and the union, as well as themselves - as is normal in occupational health and safety practice in this setting. It would have been logistically impossible to keep the subjects' names off of these reports since some would require additional follow-up because of possible excess loading indicative of potentially unsafe work. On such occasions, it was agreed by all parties that the jobs would be recommended by the study to receive further investigation from the company, with a review of the circumstances of the assessment by an joint ergonomics committee to be set up with labour, management and investigator participation. Further details about the PLR are available in Appendix 5.3(e).

Signed, informed consent was obtained prior to data collection and storage of data complied with the usual confidentiality requirements (double locking, no identifiers in databases other than subject study number, etc.). A final consideration was a commitment by the principal investigators to not release the results of the study in a broad public forum until the company and the union had been given the opportunity to review them first. This step was considered essential to demonstrating the commitment to the partnership required to complete such a large and difficult study.


5. SF-36 Health survey. Scoring algorithms & test dataset for physical (PCS) & mental (MCS) summary measures. Ware JE, Jr. 1994; SF-36 ed.


RESULTS

Introduction

This chapter is divided into four main areas, structured according to Stages I-IV of the Analytic Methods outlined in the previous chapter.

Stage I summarizes the study accrual, including a review of the "capture" of WCB LBP claims filed during the study time frame.

Stage II provides a detailed description of the study population, comparing cases and controls on a number of typical demographic and individual characteristics, as well as contrasting the two groups on a wide range of clinical variables that describe their back pain and general health status. These descriptive data provide a thorough profile of the study population, describing in detail the relevant clinical features of the subjects’ back pain, particularly for the cases.

Stage III of the analysis was meant to address the main study objective of identifying risk factors for LBP from the biomechanical and psychosocial exposure data collected. The results presented in this section begin with a series of bivariable comparisons between cases and controls for each of the study’s suspected risk factors. The next step in this analysis was to explore the relative independent effect of each of these risk factors by using multiple logistic regression analysis.

Stage IV of the analysis addressed the study’s supplementary objectives. The first of these was to assess the validity of using proxy biomechanical data from job-matched controls for cases who did not have the physical demands of their jobs measured. Possible misclassification bias from these proxy data is examined by re-running the study’s main risk factor model after excluding the cases using proxy data. The second supplemental analysis relates to possible case misclassification
by including controls with unreported LBP. Once again, the results of a sensitivity-type analysis are presented to address this objective.

**Stage I: Study Accrual**

The study received notification of 324 workers who had reported LBP to one of the nursing stations. Of these 324 workers, 56 (17.3%) refused to have their names passed to the study team, and 17 could not be contacted, leaving a total of 251 names of workers with reported LBP. A further 66 workers were withdrawn because they were found to be ineligible - 45 with a LBP report in the previous 90 days, 12 with non-LBP, and 9 others. Of the remaining 185 potential cases, 26 refused at the first contact (eligibility not known) and a further 22 refused at some later point, after initially agreeing, leaving a total of 137 cases enrolled in the study.

<table>
<thead>
<tr>
<th>Controls</th>
<th>Cases</th>
<th>Random</th>
<th>Job-matched</th>
</tr>
</thead>
<tbody>
<tr>
<td># of potential contacts</td>
<td>324</td>
<td>565</td>
<td>134</td>
</tr>
<tr>
<td>refusals (eligibility unknown)</td>
<td>82</td>
<td>253</td>
<td>30</td>
</tr>
<tr>
<td>refusals (eligible)</td>
<td>22</td>
<td>28</td>
<td>13</td>
</tr>
<tr>
<td>no contact</td>
<td>17</td>
<td>78</td>
<td>4</td>
</tr>
<tr>
<td>ineligible (established)</td>
<td>66</td>
<td>27</td>
<td>22</td>
</tr>
<tr>
<td>participating subjects (interviewed)</td>
<td>137</td>
<td>179</td>
<td>65</td>
</tr>
<tr>
<td>crude participation rate</td>
<td>42.3 (137/324)</td>
<td>31.7 (179/565)</td>
<td>48.5 (65/134)</td>
</tr>
<tr>
<td>Contact-adjusted participation rate</td>
<td>44.6 (137/[324-171])</td>
<td>36.8 (179/[565-78])</td>
<td>50.0 (65/[134-4])</td>
</tr>
<tr>
<td>% estimated to be ineligible</td>
<td>29.3</td>
<td>11.5</td>
<td>16.9</td>
</tr>
<tr>
<td>Eligibility-adjusted participation rate</td>
<td>60.0 (137/[324-96])</td>
<td>35.8 (179/[565-78])</td>
<td>58.6 (65/[134-23])</td>
</tr>
</tbody>
</table>

Table 6.1: Outline of subject accrual and participation.

*Due to the staggered entry of the truck and car plants, this represents an overall 12 month incidence rate of 2.3% for reports to the nursing stations by worker with acute LBP (324 LBP reports with 13,856 person years).*
Of the 487 potential random controls contacted, slightly over half refused to participate. A further 27 were ineligible (24 prior LBP report, 3 other reasons), and an additional 28 refused at a later point, thus 179 random controls were enrolled. (The high number without contact, 78/565 or 13.8%, may be an indication of the company's personnel records being out-of-date.) For the job-matched controls, 30 refused to participate at the initial study contact, with 22 ineligible (20 for recent reporting of LBP, 2 for other reasons). A further 13 refused after initially agreeing to participate, leaving a total of 65 enrolled.

Because of the high number of ineligible subjects, mostly because of recent LBP problems reported to the nursing station, the “eligibility-adjusted participation rate” in Table 6.1 represents the best estimate of a proper study participation rate. Based on this calculation, about 60% of the eligible workers approached by the study team agreed to participate. (The “%estimated to be ineligible” is based on the number known to be ineligible divided by the total number with known eligibility.)

Based on a roster of WCB LBP claims provided by the company, the study “capture” of WCB claimants was estimated to be 24% (90 of the 381 WCB claims from the list supplied by the company agreed, via the nurses, to be contacted by the study team). A comparison of these two groups of WCB claimants on basic descriptive variables available in the WCB database is shown in Table 6.2.

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>Name to IWH(90)</th>
<th>Name NOT to IWH (291)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>age (years)</td>
<td>42.5</td>
<td>42.2</td>
<td>0.78</td>
</tr>
<tr>
<td>claim duration (days)</td>
<td>26.0</td>
<td>27.1</td>
<td>0.81</td>
</tr>
<tr>
<td>Current job experience (years)</td>
<td>3.32</td>
<td>2.96</td>
<td>0.57</td>
</tr>
<tr>
<td>% male</td>
<td>91.1</td>
<td>91.4</td>
<td>0.93 (f²)</td>
</tr>
</tbody>
</table>

Table 6.2: Comparing WCB accrued claims with those not accrued.
The data used to compile Table 6.2 came from the WCB itself, not the company files, to which we did not have access. The results of this comparison suggest there were no significant differences between those workers who were recruited and those who were not when looking at age, gender, years of experience or claim duration, the only descriptive data available for making comparisons.

As previously mentioned, a total of 137 cases and 179 randomly selected controls were successfully recruited. Each of these workers was interviewed for the study. Unless otherwise indicated, particularly for the biomechanical variables which were available on only about 75% of the subjects, these are the numbers of subjects included in the results presented below. These figures represent about 91% and 119% of the intended sample sizes for the case and random control groups respectively. Although not in the original study protocol, the surplus in random controls was intentional. It was recognized early on in the study that because accrual was slower than expected, we would probably need to offset, at least partially, a projected reduction in study power from a combination of reduced case recruitment and a lower-than-expected completion rate for the biomechanical assessments. The actual number of additional random controls that could be accrued was determined by the availability of any unused capacity within the biomechanical assessment team - i.e. when they were not busy with case assessments, or assessments of job-matched controls of cases known not to be getting an assessment, these additional controls could be included.

Of the 137 cases, 105 had biomechanical data, either from their own assessment (n=85) or from the assessment of a job-matched control (n=20). Most of the cases without an assessment had either changed jobs or the job had changed before it could be assessed (n=22) or they refused the assessment (n=19). Other reasons included the significant logistical difficulties encountered when booking the
assessments (n=9). The fact that about three-quarters of the subjects had data for the biomechanical variables (directly or by proxy) is a testament to the commitment of the subjects and the perseverance of the assessment teams to the study.

Stage II: Describing the Study Population

Basic Demographics

Table 6.3 presents the basic demographic data collected from the study subjects. It is evident from this data that there are no major differences between the cases and the randomly chosen controls on any of the potential confounder variables that were examined (as measured by a t-test for continuous factors and a chi square test

<table>
<thead>
<tr>
<th>Continuous variables:</th>
<th>group mean (sd)</th>
<th>t-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case</td>
<td>Control</td>
<td></td>
</tr>
<tr>
<td>age (yrs)</td>
<td>41.1 (8.5)</td>
<td>41.5 (8.2)</td>
<td>0.63</td>
</tr>
<tr>
<td>height (cm)</td>
<td>177.2 (7.1)</td>
<td>176.2 (7.0)</td>
<td>0.23</td>
</tr>
<tr>
<td>weight (kg)</td>
<td>83.6 (14.2)</td>
<td>83.4 (13.3)</td>
<td>0.87</td>
</tr>
<tr>
<td>body mass index (BMI)</td>
<td>26.6 (3.9)</td>
<td>26.8 (3.9)</td>
<td>0.60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Categorical variables:</th>
<th>Case (%)</th>
<th>Control (%)</th>
<th>$\chi^2$</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>sex (male)</td>
<td>92.0</td>
<td>92.7</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>current smoker</td>
<td>45.3</td>
<td>41.9</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td>main wage earner in household</td>
<td>81.8</td>
<td>78.8</td>
<td>0.51</td>
<td></td>
</tr>
<tr>
<td>lives with pre-school children</td>
<td>21.2</td>
<td>19.0</td>
<td>0.63</td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>76.5</td>
<td>84.8</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>alcohol consumption in past year</td>
<td>..</td>
<td>..</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>- NONE</td>
<td>11.7</td>
<td>9.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 1-2 per month</td>
<td>16.1</td>
<td>14.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 1-2 per week</td>
<td>31.3</td>
<td>38.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- daily</td>
<td>13.8</td>
<td>11.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- &gt;= 2/day</td>
<td>5.1</td>
<td>2.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>highest completed education level</td>
<td>..</td>
<td>..</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td>&lt; high-school</td>
<td>30.7</td>
<td>28.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>high-school</td>
<td>46.0</td>
<td>44.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; high-school</td>
<td>23.3</td>
<td>26.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.3: Selected demographic characteristics of the study population.
for categorical variables). In very general terms, the subjects in the two groups can be described as middle-aged men of average height, who have a high prevalence of smoking, but are moderate drinkers. They typically had a high school education, were their family’s main wage earners, and were mostly married. Although most had children, relatively few had any preschool children living with them. With the exception of marital status, which was of borderline statistical significance at p=0.06, none of the variables showed any clinically significant relationship to case/control status. Of the few subjects who were not living as married (i.e. single, divorced or separated), slightly more were cases than controls.

Marital status was originally collected as a four-category interview response item: married (or common-law); single (never married); widow/widower; or separated/divorced. The last two categories had very small cell frequencies. Only the single (never married) category showed any marked difference between cases and controls, although this was applicable to only a small proportion of subjects. Because of the pattern observed and the fact that having the support of a spouse or partner at home could, at least in theory, influence the decision of whether or not to report back pain to the nursing station, the marital status variable was recoded to a dichotomous term (married, yes/no) for the main risk factor analyses.

**Employment and Activity-related Variables**

Table 6.4 compares cases and random controls on a number of general employment-related variables. Once again, it is evident that there are no major differences between the two groups on any of the factors presented. The length of time at the current job may appear low, but it is explained by the fact that we were asking about the current job in its exact form, rather than just the number of years with the company. There was a much higher degree of worker mobility within the plants than we expected before starting the study, thus the average specific job tenure was
Table 6.4: Employment and activity-related variables

<table>
<thead>
<tr>
<th>Continuous variables:</th>
<th>group mean (sd)</th>
<th>t-test p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>time at current job (years)</td>
<td>1.2 (4.5)</td>
<td>1.4 (4.3)</td>
</tr>
<tr>
<td>commuting time (minutes)</td>
<td>28.9 (18.2)</td>
<td>28.2 (9.17)</td>
</tr>
<tr>
<td>number of non-occupational</td>
<td>3.2 (3.7)</td>
<td>2.7 (2.5)</td>
</tr>
<tr>
<td>physical activities per week</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Categorical variables:</th>
<th>Case (%)</th>
<th>Control (%)</th>
<th>( \lambda^2 ) p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>has an apprenticeship</td>
<td>19.7</td>
<td>18.4</td>
<td>0.78</td>
</tr>
<tr>
<td>required to do shift work</td>
<td>81.0</td>
<td>85.4</td>
<td>0.30</td>
</tr>
<tr>
<td>ever changed a prior job</td>
<td>9.6</td>
<td>14.2</td>
<td>0.35</td>
</tr>
<tr>
<td>because of back pain?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>type of occupation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>production operator</td>
<td>50.4</td>
<td>49.2</td>
<td></td>
</tr>
<tr>
<td>support worker</td>
<td>24.1</td>
<td>22.9</td>
<td></td>
</tr>
<tr>
<td>maintenance worker</td>
<td>10.9</td>
<td>8.9</td>
<td></td>
</tr>
<tr>
<td>utility worker</td>
<td>14.6</td>
<td>19.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 6.4: Employment and activity-related variables

short. Although this mobility may have implications for studies focusing on long term exposure, it is not likely of explanatory value for this setting because no significant difference was observed for job tenure by case and control status. The mean number of years reported in the current job was influenced by a few people from the skilled trades with very long tenures, hence the use of a log-transformed term. The raw job tenure means were 3.23 and 3.27 and the medians were 1.08 and 1.75 for cases and controls respectively, with a t-test p-value of 0.95 for the difference between the mean values. In both groups, the average commuting time was about half an hour, with the workers' homes being widely distributed around the Oshawa area, ranging as far as 100 kilometres from the plant. Prior to the onset of LBP, cases seemed to be slightly more physically active outside of work than controls, although the difference was not statistically significant.
Only the small fraction of plant employees working in the skilled trades required an apprenticeship, hence the low proportions shown in Table 6.4. Almost all workers are required to alternate, every two weeks, between a day shift and an evening shift. During the study accrual period, the truck plant was operating for 24 hours a day because of high product demand, using the two regular shifts as well as an overnight (midnight) shift that did not rotate. The majority of subjects not on rotating shifts were these night workers. Controls reported permanently changing their jobs in the past because of back pain slightly more often than cases, although again the difference was statistically non-significant. Assuming the change would be to a job with lower physical demands, this could be an indication that controls might have had systematically "lighter" jobs than cases. The impact of this job "drift" should be low however, since the proportion of subjects changing jobs (for this reason) in either group was quite small, with a t-test p-value of 0.35.

Finally, about half of the cases and controls can be classified as "production operators", directly involved in the building of the vehicles, about a quarter as "support workers", with the remainder being more or less equally split between "maintenance" and "utility workers".

**Back Pain-Related Variables**

This section addresses the issue of severity of back pain among the cases enrolled in the study. Cases did not have to demonstrate the presence of specific clinical, neurological or radiological signs for inclusion, nor did they require any formal lost time from work. As a result, it was felt that critics of the study might have some concern that the cases did not have "serious" back pain. Evidence presented below effectively dismisses this concern, by demonstrating that the cases show all the features typical of acute back pain.
One of the purposes of summarizing the study population’s clinical profile is to demonstrate that there was indeed a marked distinction between cases and controls, and that cases clearly demonstrate more severe low-back pain symptomatology than controls. At the same time, cases and controls do not appear to differ strongly on other health-problems, as measured by either their levels of the most common co-morbidities or their health-related quality of life. None of this clinical data, apart from a prior history of WCB claims, was used in the risk factor analyses. No a priori hypotheses about possible roles in the causal chain were formulated for these variables. Rather, they were regarded as probable co-outcomes - i.e. more likely a feature or a consequence of LBP than a cause of it. (Having a prior history of WCB claims was, however, controlled for in the final analysis because of its wide reporting in the occupational LBP literature as a possible confounder.)

Table 6.5 shows that for most of the variables assessing prior history of back pain,

<table>
<thead>
<tr>
<th>Categorical variables:</th>
<th>Case (%)</th>
<th>Control (%)</th>
<th>$f^2$ p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>prior back surgery</td>
<td>0</td>
<td>2.2</td>
<td>n/a¹</td>
</tr>
<tr>
<td>other hospitalizations for back</td>
<td>8.1</td>
<td>5.6</td>
<td>0.39</td>
</tr>
<tr>
<td>prior lifetime LBP episodes (excludes current episode for cases)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>13.1</td>
<td>16.9</td>
<td>n/a²</td>
</tr>
<tr>
<td>1 to 5</td>
<td>42.3</td>
<td>41.0</td>
<td></td>
</tr>
<tr>
<td>&gt; 5</td>
<td>44.5</td>
<td>42.1</td>
<td></td>
</tr>
<tr>
<td>Back pain in last year (excludes current episode for cases)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Categories NOT mutually exclusive)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>49.6</td>
<td>37.4</td>
<td>n/a²</td>
</tr>
<tr>
<td>≥ 1 day duration</td>
<td>48.1</td>
<td>49.2</td>
<td></td>
</tr>
<tr>
<td>≥ 1 week duration</td>
<td>32.1</td>
<td>27.4</td>
<td></td>
</tr>
<tr>
<td>≥ 5 episodes of ≥ 1 day</td>
<td>27.7</td>
<td>28.4</td>
<td></td>
</tr>
<tr>
<td>prior WCB claim for LBP</td>
<td>51.1</td>
<td>31.8</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Table 6.5: Prior history of low-back pain (excludes current episode).
there are no significant differences between cases and controls. However, since the LBP data were also to be used for the prognostic cohort study, cases were asked to separate the current LBP episode from past episodes for the questions on prior lifetime LBP and LBP in the past year. Many cases indicated at the interview that they had difficulty separating current and prior LBP. Since the separation was asked only of the cases, there was concern that their data may be underestimated, thus no statistical tests were done to compare cases and controls. The only exception was the higher proportion of cases reporting that they had filed a WCB claim for at least one of their prior back pain episodes. It is interesting to note that cases and controls did not differ significantly on the number of prior episodes of pain, either lifetime or in the past year. As expected, it does appear that back pain is a common problem for our study population, as only 13 percent of our cases reported first-time LBP events and over 80 percent of the random controls had experienced one or more back pain episodes during their lifetime.

<table>
<thead>
<tr>
<th>Categorical variables:</th>
<th>Case (%)</th>
<th>Control (%)</th>
<th>$f^2$ p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>back or leg pain (sciatica) in last week</td>
<td>90.5</td>
<td>31.8</td>
<td>0.001</td>
</tr>
<tr>
<td>possible sciatica</td>
<td>24.1</td>
<td>5.6</td>
<td>0.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Continuous variables:</th>
<th>Case group mean (sd)</th>
<th>Control group mean (sd)</th>
<th>t-test p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roland back pain disability score</td>
<td>11.7 (7.0)</td>
<td>2.5 (5.0)</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Table 6.6: Measures assessing current back pain-related health.

As shown in Table 6.6 above, and Figures 6.1 and 6.2 below, cases are significantly worse off than controls for current back pain-related variables, especially for back pain-related disability, as measured by the Roland Disability scale. As expected,
based on prior studies, a significant proportion of controls (32%) reported having LBP in the week prior to interview, although this was much lower than the cases, almost all of whom still had LBP at interview (91%). The proportion of cases with
possible sciatica, defined as self-reported pain radiating from the back to below the knee, is 24%, compared to only 6% of controls. Pain severity was assessed by a modified version of the Von Korff pain grade. (The data represented in Figure 6.2 are a composite of two slightly different versions of this instrument, thus no formal statistical tests were conducted.)

**Baseline Physical Exam**

No data are reported for reflex measurements due to problems experienced with this procedure by the interviewers. As shown in Table 6.7, there was a clear delineation between cases and controls on their performance in the exam, with cases being worse off on all measures. Cases exhibit clinical profiles typical of acute low-back pain patients seen in primary care, with a considerably reduced level of flexibility, as indicated by the large gap in the finger-floor distance and the poorer scores for leg raising and sit-ups. The grip strength of the cases is about 10% lower than that for controls, possibly indicating a "generalized weakness" consequence of back pain. Cases also have about twice as many tender-points on average, although this difference, as well as the one for sit-ups, may be somewhat

<table>
<thead>
<tr>
<th>Exam variable</th>
<th>group mean (sd)</th>
<th>t-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case</td>
<td>Control</td>
<td></td>
</tr>
<tr>
<td>finger-to-floor distance (cm)</td>
<td>19.1 (18.0)</td>
<td>6.3 (11.9)</td>
<td>0.0001</td>
</tr>
<tr>
<td>straight leg raising (degrees)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>left</td>
<td>61.5 (19.2)</td>
<td>72.1 (16.0)</td>
<td>0.0001</td>
</tr>
<tr>
<td>right</td>
<td>61.4 (19.2)</td>
<td>71.2 (16.6)</td>
<td>0.0001</td>
</tr>
<tr>
<td>sit-up score (0-6)</td>
<td>3.2 (2.6)</td>
<td>5.3 (1.7)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Grip strength (N)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>left</td>
<td>461.0 (115.5)</td>
<td>504.0 (124.6)</td>
<td>0.0001</td>
</tr>
<tr>
<td>right</td>
<td>467.8 (122.5)</td>
<td>508.5 (126.4)</td>
<td>0.0001</td>
</tr>
<tr>
<td>tender points (n)</td>
<td>4.3 (3.3)</td>
<td>2.1 (2.7)</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Table 6.7: Baseline physical exam data.
underestimated as several cases reported that they could not complete either procedure because of their pain.

**Other Health-Related Variables**

The results of comparing the cases and controls on the SF-36 sub-scales are shown in Table 6.8. The only clinically significant differences between cases and controls occurs with the scales that are most directly linked to back pain, specifically the scales that assess the impact of pain and physical disability on a person’s life.

<table>
<thead>
<tr>
<th>SF-36 sub-scale scores</th>
<th>group mean (sd)</th>
<th>t-test p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case</td>
<td>Control</td>
</tr>
<tr>
<td>Physical functioning</td>
<td>60.6 (29.0)</td>
<td>86.7 (18.5)</td>
</tr>
<tr>
<td>Role physical</td>
<td>25.4 (36.9)</td>
<td>81.3 (32.7)</td>
</tr>
<tr>
<td>Bodily pain</td>
<td>38.5 (23.9)</td>
<td>74.4 (22.0)</td>
</tr>
<tr>
<td>Vitality</td>
<td>46.8 (22.3)</td>
<td>62.0 (20.6)</td>
</tr>
<tr>
<td>Social functioning</td>
<td>63.4 (30.3)</td>
<td>92.2 (14.7)</td>
</tr>
<tr>
<td>Role emotional</td>
<td>81.3 (34.7)</td>
<td>91.1 (24.9)</td>
</tr>
<tr>
<td>Mental health</td>
<td>76.3 (16.2)</td>
<td>81.7 (14.5)</td>
</tr>
<tr>
<td>General health</td>
<td>72.1 (15.6)</td>
<td>75.8 (15.9)</td>
</tr>
<tr>
<td>SF-36 summary index scores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mental health index</td>
<td>52.2 (9.1)</td>
<td>54.0 (7.4)</td>
</tr>
<tr>
<td>Physical health index</td>
<td>34.5 (9.9)</td>
<td>49.2 (8.6)</td>
</tr>
</tbody>
</table>

Table 6.8: Health-Related Quality of Life (SF-36 sub-scale scores).

This difference in pain and functional capacity is most evident in Figure 6.3, which shows the difference between case and control sub-scale scores after normalizing them to the mean scores and standard deviations of a reference population with a similar age and sex distribution (US males, aged 25-64). Cases show much higher levels of pain and disability than controls, while the differences on the scales addressing mental health and general health are clearly less pronounced, as would
be expected in subjects with acute LBP.

![ASSESSING HEALTH LIMITATIONS](image)

**Figure 6.3:** Health-related quality of life (SF-36) for cases and controls.

The results of the co-morbidity summary score are shown in Table 6.9 on the following page. Apart from back pain, the study groups were relatively healthy, on average reporting only about one additional health problem from the list provided. Although cases did report having a co-morbid condition marginally more often than did controls (means of 1.2 versus 0.9, respectively, from a maximum of 17 conditions on the list), the difference was not considered clinically important. The most commonly reported problems were hearing loss, asthma, and chronic foot trouble, with only the latter showing any marked difference by case-control status (18% versus 8% respectively - a difference which could be a chance occurrence given the number of conditions examined). There did not appear to be any difference in the prevalence of arthritis or other chronic joint pain conditions.
Categorical variables:

<table>
<thead>
<tr>
<th></th>
<th>Case (%)</th>
<th>Control (%)</th>
<th>$r^2$ p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-back chronic joint pain</td>
<td>39.7</td>
<td>34.1</td>
<td>0.30</td>
</tr>
<tr>
<td>Diagnosis of ARTHRITIS</td>
<td>17.5</td>
<td>19.1</td>
<td>0.72</td>
</tr>
</tbody>
</table>

Common health conditions for comorbidity scale (% affected)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Case (%)</th>
<th>Control (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>asthma</td>
<td>17.5</td>
<td>12.5</td>
</tr>
<tr>
<td>high blood pressure</td>
<td>9.5</td>
<td>7.8</td>
</tr>
<tr>
<td>heart trouble</td>
<td>5.1</td>
<td>1.7</td>
</tr>
<tr>
<td>balance troubles</td>
<td>10.9</td>
<td>6.7</td>
</tr>
<tr>
<td>depression/anxiety</td>
<td>8.0</td>
<td>8.9</td>
</tr>
<tr>
<td>vision loss</td>
<td>4.4</td>
<td>5.0</td>
</tr>
<tr>
<td>hearing loss</td>
<td>15.3</td>
<td>15.6</td>
</tr>
<tr>
<td>chronic foot trouble</td>
<td>18.2</td>
<td>8.4</td>
</tr>
<tr>
<td>kidney trouble</td>
<td>4.4</td>
<td>3.9</td>
</tr>
<tr>
<td>stomach ulcers</td>
<td>2.2</td>
<td>3.9</td>
</tr>
<tr>
<td>psoriasis</td>
<td>2.2</td>
<td>5.6</td>
</tr>
<tr>
<td>skin infection</td>
<td>5.8</td>
<td>1.7</td>
</tr>
<tr>
<td>intestinal disorders</td>
<td>9.5</td>
<td>5.6</td>
</tr>
</tbody>
</table>

(Cancer, stroke, epilepsy and diabetes also included but all had less than 5 subjects responding YES per group.)

<table>
<thead>
<tr>
<th>COMORBIDITY score</th>
<th>group mean (sd)</th>
<th>t-test p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(possible range 0-17)</td>
<td>Case</td>
<td>Control</td>
</tr>
<tr>
<td></td>
<td>1.2 (1.3)</td>
<td>0.9 (1.1)</td>
</tr>
</tbody>
</table>

Table 6.9: Measures assessing other common health conditions.

**Summary of the Study Population Profile**

Cases were clinically and statistically significantly different from controls on all of the measures used to assess current back pain, reporting considerably more back pain-related morbidity and disability. The cases appear to represent typical acute low-back pain patients. Based on their demographic profiles, there are no major differences between the cases and controls for most of the descriptive characteristics examined, the only exception being an excess of cases with a prior WCB LBP claim. Therefore, past and present LBP is the only significant difference in the individual characteristics of the cases and controls. Characteristics common to both study groups are a high prevalence of smoking and the obvious preponderance of males.
Stage III: The Main Risk Factor Analysis

A) The Bivariable Risk Factor Analysis

This section describes the results of simple pair-wise comparisons of the cases and random controls for the major study variables representing putative biomechanical and psychosocial risk factors for the onset of LBP.

The descriptive statistics for each bivariable analysis are presented in Appendix 6.1, page 132-133. The information in these Appendix tables includes, for each risk factor examined: the number of subjects with data; the mean; median; standard deviation; minimum; maximum; 1st (Q1) and 3rd (Q3) quartiles (or 25th and 75th percentiles); the Q3-Q1 interquartile range, which is used later as the benchmark for risk estimates for continuously scaled terms; and finally a measure of skewness. Although not presented, frequency plots (by case/control status) were also used to visually examine distributions for each bivariable analysis.

The data in Appendix 6.1 show that none of the variables examined for this study were very heavily skewed. A few of the biomechanical terms, such as peak hand load and awkward posture, did exhibit moderate levels of skewness, with a small number of outlying observations skewing the distributions somewhat to the right (making the mean larger than the median). These outliers were noted for the diagnostic procedures used in the examination of the final multivariable model obtained in Part B of the risk factor analysis reported below.

The data presented from each bivariable analysis include: the group means and standard deviations; a t-test p-value for the statistical significance of the difference between the means; and finally the odds ratio estimate and its corresponding 95% test-based confidence interval, based on the interquartile range from the exposure distribution of the random controls. The variables are presented in a rank order -
with the strongest associations (based on the OR estimate) found at the top of the table, the weakest found at the bottom.

Biomechanical Factors

The results in the Table 6.10 clearly show that cases and controls differ considerably in the measured biomechanical demands of their jobs. For all variables cases have higher mean values of exposure than controls, and all comparisons except the difference in low loading levels are statistically significant. The consistency of these results is remarkable, especially given that they measure very different components of the job demands.

<table>
<thead>
<tr>
<th>VARIABLE (unit)</th>
<th>CASE mean (sd)</th>
<th>N</th>
<th>CONTROL mean (sd)</th>
<th>N</th>
<th>t-test p-value</th>
<th>Q3-Q1 Range^a</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Flexion (degrees)</td>
<td>51.2 (22.3)</td>
<td>105</td>
<td>39.2 (23.3)</td>
<td>129</td>
<td>0.0001</td>
<td>39 degrees</td>
<td>2.4 (1.54, 3.83)</td>
</tr>
<tr>
<td>Peak SHEAR (N)</td>
<td>461.7 (177.8)</td>
<td>105</td>
<td>354.0 (159.0)</td>
<td>129</td>
<td>0.0001</td>
<td>190 (N)</td>
<td>2.1 (1.54, 3.00)</td>
</tr>
<tr>
<td>Peak Load - Dynamic or Static (kg)</td>
<td>24.4 (23.5)</td>
<td>105</td>
<td>14.3 (12.4)</td>
<td>129</td>
<td>0.0001</td>
<td>17 (kg)</td>
<td>1.9 (1.37, 2.61)</td>
</tr>
<tr>
<td>Peak COMPRESSION (N)</td>
<td>3402 (1429)</td>
<td>105</td>
<td>2744 (1070)</td>
<td>129</td>
<td>0.0001</td>
<td>1325 (N)</td>
<td>1.8 (1.33, 2.44)</td>
</tr>
<tr>
<td>Peak flexor velocity (deg/s)</td>
<td>41.3 (15.2)</td>
<td>105</td>
<td>34.2 (17.3)</td>
<td>129</td>
<td>0.0011</td>
<td>22.6 (deg/s)</td>
<td>1.8 (1.27, 2.66)</td>
</tr>
<tr>
<td>Average Compression (N)</td>
<td>899.7 (205.0)</td>
<td>104</td>
<td>826.3 (158.3)</td>
<td>130</td>
<td>0.0030</td>
<td>231.1 (N)</td>
<td>1.7 (1.20, 2.38)</td>
</tr>
<tr>
<td>Peak extensor velocity (deg/s)</td>
<td>-42.5 (16.8)</td>
<td>105</td>
<td>-35.9 (18.5)</td>
<td>129</td>
<td>0.0050</td>
<td>25.5 (deg/s)</td>
<td>1.7 (1.17, 2.53)</td>
</tr>
<tr>
<td>Integrated compression (Ns/shift)</td>
<td>1.48x10^7 (1.01x10^7)</td>
<td>105</td>
<td>1.22x10^7 (6.65x10^6)</td>
<td>129</td>
<td>0.0218</td>
<td>7.8 x 10^4 Ns/shift</td>
<td>1.4 (1.06, 1.80)</td>
</tr>
<tr>
<td>Time in any awkward posture (% time)</td>
<td>20.9 (19.6)</td>
<td>105</td>
<td>14.9 (16.5)</td>
<td>129</td>
<td>0.0121</td>
<td>18.5 (% time)</td>
<td>1.4 (1.08, 1.89)</td>
</tr>
<tr>
<td>Number of (sagittal) back moves/min</td>
<td>2.9 (2.1)</td>
<td>105</td>
<td>2.3 (2.3)</td>
<td>129</td>
<td>0.0362</td>
<td>2.9 (l/min)</td>
<td>1.4 (1.02, 2.05)</td>
</tr>
<tr>
<td>Low Loading - Compression (N)</td>
<td>545.5 (103.8)</td>
<td>105</td>
<td>540.3 (94.50)</td>
<td>130</td>
<td>0.6929</td>
<td>175.9 (N)</td>
<td>1.1 (0.69, 1.75)</td>
</tr>
</tbody>
</table>

(a = Interquartile range of random control distribution used as the benchmark for determining OR estimates)

( Legend: t-test p-value < 0.05; p-value > 0.25)

Table 6.10: Summary of Bivariable Comparisons of Biomechanical Data.
The odds ratio estimates vary from 1.1 to 2.4, with most being close to 2. If the scaling of these estimates is extended to more extreme values, such as the difference between the 95th and 5th percentiles, then the risk estimates increase substantially to values with a range of 3 to 6. The strongest bivariable risk factor associations were for peak flexion and peak shear, both of which had OR estimates just over 2.

**Psychosocial Factors**

The results of the bivariable analysis of the remaining risk factors are found in Table 6.11. It is evident the consistency of the associations for the self-reported psychosocial risk factors with LBP is lower than that observed for the directly measured biomechanical variables.

Some factors, such as higher levels of psychological demands, affected risk in the expected way, with subjects who report high psychological demands appearing to be at greater risk of LBP. Other factors affected risk in an unexpected way. Workers who perceived their work as being important were more likely to have reported LBP in this study and there was some evidence to suggest that workers who reported a positive feeling about their job in general (job satisfaction) or who reported higher levels of co-worker support were also at greater LBP risk. Finally, a number of factors, like supervisor social support, job control, coping behaviour and recently stressful life-events, appear to have no effect on LBP risk at all. In general, when the variables are examined separately, the strongest risk factors appear to be those that relate to the self-reported demands of work, either psychological or physical. There may be some concern about labelling self-reported “physical” work demands as “psychosocial” risk factors. However, because this study also used directly measured estimates of the physical demands of work, the results of all of the self-reported variables are combined here mainly for ease of presentation.
Table 6.11: Bivariable Comparisons for Psychosocial Data

The strength of the associations for the self-reported risk factors found in Table 6.11 are roughly in the same range as those found for the direct biomechanical measures in Table 6.10, with OR estimates (for the interquartile range of the random controls) ranging from 1 to 2.6. The strongest association was the almost threefold increase in risk associated with a perception that one’s job is physically demanding on the body (the Borg Scale). Perceptions of increased physical exertion, a poor workplace
social environment, increased psychological demands, and a feeling of being "over-educated" relative to other workers in similar jobs show somewhat lower effect-sizes, each approximately doubling risk.

The distributions of the psychosocial variables, shown in Appendix 6.1, showed that none were strongly skewed. In all cases, the ranges of the composite variables were at or very near their maximum possible values, with each being normally distributed around the mean (i.e. typical Gaussian distributions).

**B) Correlation and Restricted Multiple Regression**

**Biomechanical Factors**

The results of the correlation matrix for the biomechanical factors are shown in Appendix 6.2a, page 134. As one might expect, the correlation between several of the variables is quite high, particularly those that measure biomechanical forces in the lumbar spine. Several correlations exceeded 0.80, indicating that the number of variables could be reduced before the final multiple regression modelling stage started. These very high correlations occurred between the two terms assessing trunk velocity \((r=0.94)\), and between these two trunk velocity terms and the variable assessing the number of back bends per minute \((r=-0.84\) and 0.82 for extensor and flexor velocity respectively). A similar level of correlation occurred between peak shear and peak compression \((r=0.83)\).

Due to the high degree of correlation observed between the biomechanical terms, a restricted multiple logistic regression model, including only the 11 biomechanical variables, was developed. Its purpose was to identify the most important biomechanical variables for inclusion in the final regression analysis, that combined risk factors from the biomechanical, psychosocial and individual-worker characteristic domains. The same backwards regression procedure described in the
Methods chapter for the final analysis, was used to arrive at parsimonious model to account for the most important terms among the biomechanical factors alone.

The key findings from this analysis suggest that the most important biomechanical risk factors from the set of variables examined include the peak shear force in the lumbar spine, peak hand force observed and the combined disc compression experienced over a total shift. The high correlation between peak shear and peak compression, together with the stronger effect-size for peak shear, resulted in peak compression being dropped from the restricted regression model. Due to the high correlation and similarity in the descriptive statistics between the three variables assessing trunk motion (at the hips), only peak flexion velocity was identified as being sufficiently independent for retention in the combined multiple regression modelling stage. Other variables that showed effects of arguably borderline statistical significance (p-value > 0.05 but < 0.25) included peak flexion, time in awkward postures, and average disc compression. All were retained for the next regression phase that combined, as independent variables, the biomechanical and psychosocial factors together with the individual-worker characteristics.

**Psychosocial Factors**

Unlike the biomechanical variables, none of the Pearson correlation coefficients for the self-reported terms approached a value of 0.8 (see Appendix 6.2b, page 135.) The strongest correlations were between the two variables addressing perceived physical demands, the JCI physical exertion scale and the Borg scale (r=0.62), and between the JCI exertion scale and the JCI psychological demands scale (r=0.62). None of the other correlations were above 0.6. As a result, all of the psychosocial variables, except troubling personal experiences, were retained for the starting model of the combined multiple regression analysis. The latter dichotomous variable was dropped because it showed no effect at all in the bivariable analysis.
C) Combined Multiple Logistic Regression

Table 6.12 shows the terms included at the start of the modelling process, as well as OR estimates and their 95% confidence intervals. The variables are grouped according to the three basic domains (individual, psychosocial, biomechanical), and then ranked from highest to lowest OR, with those variables having individual coefficients at $p < 0.05$ shown first (in bold).

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>OR</th>
<th>95% CI</th>
<th>Risk Comparison Used¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior WCB LBP claims</td>
<td>2.4</td>
<td>1.14, 5.07</td>
<td>Yes versus No</td>
</tr>
<tr>
<td>Lives with a spouse/partner</td>
<td>1.6</td>
<td>0.61, 4.39</td>
<td>No versus Yes</td>
</tr>
<tr>
<td>Cigarette smoker (current)</td>
<td>1.4</td>
<td>0.67, 2.95</td>
<td>Yes versus No</td>
</tr>
<tr>
<td>Preschool children in the home</td>
<td>1.1</td>
<td>0.37, 3.06</td>
<td>Yes versus No</td>
</tr>
<tr>
<td>Age (older)</td>
<td>0.9</td>
<td>0.46, 1.68</td>
<td>12 years</td>
</tr>
<tr>
<td>Body Mass Index (heavier)</td>
<td>0.6</td>
<td>0.38, 1.06</td>
<td>4.77 units higher</td>
</tr>
<tr>
<td>Poor workplace social environment</td>
<td>3.0</td>
<td>1.30, 7.14</td>
<td>3 units lower</td>
</tr>
<tr>
<td>Higher perceived exertion</td>
<td>2.6</td>
<td>1.23, 5.63</td>
<td>2 units higher</td>
</tr>
<tr>
<td>Perception of being &quot;over educated&quot;</td>
<td>2.4</td>
<td>1.06, 5.46</td>
<td>Yes versus No</td>
</tr>
<tr>
<td>Better job satisfaction</td>
<td>1.6</td>
<td>1.03, 2.39</td>
<td>1 unit higher</td>
</tr>
<tr>
<td>Low job control</td>
<td>2.2</td>
<td>0.93, 5.57</td>
<td>32 units lower</td>
</tr>
<tr>
<td>Borg physical demands scale</td>
<td>2.0</td>
<td>0.94, 4.30</td>
<td>4 units higher</td>
</tr>
<tr>
<td>Better supervisor support</td>
<td>1.5</td>
<td>0.76, 3.16</td>
<td>5 units higher</td>
</tr>
<tr>
<td>Better job self-identity</td>
<td>1.4</td>
<td>0.73, 2.74</td>
<td>4 units higher</td>
</tr>
<tr>
<td>Better co-worker support</td>
<td>1.3</td>
<td>0.87, 2.06</td>
<td>2 units higher</td>
</tr>
<tr>
<td>Better Empowerment</td>
<td>1.0</td>
<td>0.55, 1.83</td>
<td>3 units higher</td>
</tr>
<tr>
<td>Better mastery</td>
<td>0.9</td>
<td>0.59, 1.42</td>
<td>3 units higher</td>
</tr>
<tr>
<td>Higher psychological job demands</td>
<td>0.7</td>
<td>0.32, 1.73</td>
<td>11 units higher</td>
</tr>
<tr>
<td>Higher peak hand force</td>
<td>1.8</td>
<td>1.22, 2.94</td>
<td>17 kg higher</td>
</tr>
<tr>
<td>Higher peak shear</td>
<td>1.6</td>
<td>1.01, 2.56</td>
<td>190 N higher</td>
</tr>
<tr>
<td>Higher cumulative disc compression</td>
<td>1.6</td>
<td>1.1, 2.4</td>
<td>7.8x10⁶ Ns/shift higher</td>
</tr>
<tr>
<td>Higher peak flexion</td>
<td>1.2</td>
<td>0.43, 3.10</td>
<td>39 deg</td>
</tr>
<tr>
<td>Higher forward trunk velocity</td>
<td>1.1</td>
<td>0.53, 2.22</td>
<td>22.6 deg/s higher</td>
</tr>
<tr>
<td>Worse awkward posture index</td>
<td>1.0</td>
<td>0.63, 1.70</td>
<td>18.5 %</td>
</tr>
<tr>
<td>Higher average compression</td>
<td>0.9</td>
<td>0.51, 1.72</td>
<td>231.1 N higher</td>
</tr>
</tbody>
</table>

1. Yes refers to dichotomous terms comparing people with the exposure to those without it. The OR’s for the remaining continuous variables are expressed in terms of the inter quartile range for the random controls. Bold face type indicates variables with $p$-value < 0.05

Table 6.12: Results of the starting regression model (N = 94 cases, 124 controls).
It is worth noting here that the effective sample size for the combined regression analysis is considerably lower than the 137 cases and 179 controls who were enrolled. Several subjects had missing data on one or more of the model terms, so that the effective sample size was reduced to 94 cases and 124 controls for the full model, and 97 cases and 124 controls for the final model. Most of the sample size loss was attributable to subjects not having data for the biomechanical variables because their jobs were not assessed (cases, n=32; controls, n=50).

The variables removed from the starting model by the backwards logistic regression procedure are shown below in Table 6.13, presented in the order in which they were removed. Note that the OR’s shown are from the BIVARIABLE analyses. None of these variables had a statistically significant effect on the multiple regression model, either as a main effect (i.e. regression p-value was above 0.05) or as a confounder (they did not change the coefficients of remaining significant terms by more than 10%). Based on the results of this analysis, there is insufficient evidence to conclude that these variables are risk factors for LBP reported at the study worksite.

<table>
<thead>
<tr>
<th>Variable</th>
<th>BIVARIABLE OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empowerment</td>
<td>0.8 (0.64, 1.06)</td>
</tr>
<tr>
<td>Awkward posture index</td>
<td>1.4 (1.08, 1.89)</td>
</tr>
<tr>
<td>Average compression</td>
<td>1.7 (1.20, 2.38)</td>
</tr>
<tr>
<td>Peak flexion velocity</td>
<td>1.8 (1.27, 2.66)</td>
</tr>
<tr>
<td>Mastery</td>
<td>0.9 (0.74, 1.19)</td>
</tr>
<tr>
<td>Psychological job demands</td>
<td>1.7 (1.15, 2.43)</td>
</tr>
<tr>
<td>Job self-identity</td>
<td>1.5 (1.08, 2.07)</td>
</tr>
<tr>
<td>Peak flexion</td>
<td>2.4 (1.54, 3.83)</td>
</tr>
<tr>
<td>Supervisor support</td>
<td>0.9 (0.60, 1.24)</td>
</tr>
<tr>
<td>Borg physical demands scale</td>
<td>2.6 (1.84, 3.86)</td>
</tr>
</tbody>
</table>

Table 6.13: Variables dropped from final model during backwards regression.

---

b Because multiple logistic regression simultaneously adjusts for each of the terms in the model, a subject with missing data on any of the model terms cannot be properly accounted without resorting to methods of data imputation, and thus is dropped out of the analysis.
The final model variables and their OR estimates are shown in Table 6.14. To account for basic individual worker differences, these results are also adjusted for age, body mass index, smoking, marital status, having preschool children in the home, and prior WCB history for LBP. Apart from prior WCB history (OR 2.2, 95% CI 1.22 - 3.54) and higher body mass index (0.6, 0.37, 0.95), none of these factors was significantly associated with LBP. The variables are ranked by the size of the OR, within the psychosocial and biomechanical risk factors groups.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>OR</th>
<th>95% CI</th>
<th>Unit of Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher perceived exertion</td>
<td>3.2</td>
<td>1.91, 5.70</td>
<td>2 units higher</td>
</tr>
<tr>
<td>Poor workplace social environment</td>
<td>2.8</td>
<td>1.42, 5.84</td>
<td>3 units lower</td>
</tr>
<tr>
<td>Perception of being “over-educated”</td>
<td>2.3</td>
<td>1.09, 5.15</td>
<td>Yes versus No</td>
</tr>
<tr>
<td>Lower job control</td>
<td>1.9</td>
<td>0.89, 4.09</td>
<td>32 units lower</td>
</tr>
<tr>
<td>Higher job satisfaction</td>
<td>1.6</td>
<td>1.12, 2.42</td>
<td>1 unit higher</td>
</tr>
<tr>
<td>Higher co-worker support</td>
<td>1.6</td>
<td>1.06, 2.32</td>
<td>2 units higher</td>
</tr>
<tr>
<td>Higher peak shear</td>
<td>1.9</td>
<td>1.16, 3.17</td>
<td>190 N higher</td>
</tr>
<tr>
<td>Higher cumulative disc compression</td>
<td>1.9</td>
<td>1.26, 2.93</td>
<td>7.8x10⁶ Ns/shift higher</td>
</tr>
<tr>
<td>Higher peak hand force</td>
<td>1.8</td>
<td>1.15, 2.87</td>
<td>17 kg higher</td>
</tr>
</tbody>
</table>

Note: These estimates are also adjusted for age, marital status, smoking, presence of preschool children at home, BMI, and prior WCB LBP history. *Italic type indicates variables with p-value > 0.05 but < 0.25.* “Yes” in units column refers to dichotomous terms comparing subjects with the exposure to those without it. The OR's for the remaining continuous variables are expressed in terms of the inter quartile range for the random controls.

Table 6.14: Results of the final regression model (N=97 cases, 124 controls).

The final model is almost identical to the group of statistically significant variables from the starting model, with the addition of coworker support as a significant contributor in the final model. It was only of borderline statistical significance in the
starting one, as was low job control, which remained at a borderline statistical significance in the final model as well (p=0.10). It was retained in the final model because attempts to remove it significantly affected the coefficients for other model terms, particularly peak shear and peak hand force (see Appendix 6.3).

As suggested by the preliminary restricted regression analyses, the most important measured biomechanical terms are peak shear force, peak hand force and the amount of disc compression experienced over a full shift. These three risk factors all had OR estimates of just under 2, indicating that each factor may approximately double the risk for reporting LBP at the study site.

The psychosocial results are somewhat more surprising in that there appears to be a fairly strong, albeit statistically borderline, effect for job control once the measured biomechanical demands are taken into account. This effect did not appear at all when each variable was examined on its own, since the bivariable p-value for job control was 0.79 (OR=1.1 95% CI 0.72, 1.55). This suggests that there is a complex inter-relationship between job control and some of the other variables in the final model. (This topic is discussed further in Appendix 6.3, pages 136-43, which describes the results of a detailed statistical examination of the demand and control variables from the Job Content Instrument.) The earlier unexpected results for job dissatisfaction and co-worker support were retained through the multiple regression analysis, indicating that workers who are more satisfied and have better co-worker support are somewhat more likely to report LBP in this study setting.

Finally, the bivariable associations observed for perceptions of the physical demands of the job, the workplace social environment and the relative fit between the job and education all persisted in the multiple analysis. The effect size for these factors varied somewhat, with the largest OR, 3.2 and 2.8, observed for perceptions
of a physically demanding job and a poor workplace social environment respectively. The odds ratio estimates for the other terms ranged from 1.5 to 2.3.

**Goodness-of-Fit**

At no step in the analysis did the value of the H/L statistic approach the level indicating non-conformity with the logistic model. The value of the H/L statistic for the starting model was 0.54 and for the final model it was 0.98. In the final model, the adjusted $r^2$ statistic is 0.44, suggesting that the final model could explain just over 40% of the exposure variance observed between cases and controls. In the starting model, which has 10 additional terms, $r^2$ is marginally larger at 0.47. However this is a negligible difference considering the number of terms (10) that were eventually dropped. The estimate of the predictive power of the final model was slightly over 80% ($c=0.84$), as measured by the $c$ statistic, the area under the receiver operating curve (ROC). The combination of results of these three statistics - H/L, $r^2$, and $c$ - suggests that the data represent a reasonably good fit to the logistic model and that the final statistical model does a good job of accounting for differences between cases and controls.

**Regression Diagnostics**

In general, the results of the diagnostic tests indicate that the findings were not dependent on a small number of heavily influential subjects. The five most influential observations identified using the diagnostic procedures plots were removed and the final model re-run. No statistically significant changes were observed for the parameter estimates from the final model presented above.

**Stage IV: The Supplemental Analyses**

a) **Use of Proxy Biomechanical Data**

The results of the observed agreement between the cases and their job-matched
controls, based on the ICC results, are shown in Table 6.15. The rest of the results are briefly summarized below. A total of 65 job-matched pairs of cases and controls were accrued by the end of the study. While all 65 matched pairs had more-or-less complete self-reported questionnaire data, only 45 sets had the biomechanical job analysis done on both subjects in the pair.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>ICC</th>
<th>95% CI</th>
<th># of Pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time in flexed posture</td>
<td>0.80</td>
<td>0.75, 0.83</td>
<td>38</td>
</tr>
<tr>
<td>Time in any awkward postures</td>
<td>0.79</td>
<td>0.75, 0.83</td>
<td>38</td>
</tr>
<tr>
<td>Average disc compression</td>
<td>0.75</td>
<td>0.69, 0.79</td>
<td>37</td>
</tr>
<tr>
<td>Peak disc compression</td>
<td>0.70</td>
<td>0.65, 0.75</td>
<td>38</td>
</tr>
<tr>
<td>Peak extensor velocity</td>
<td>0.64</td>
<td>0.57, 0.70</td>
<td>38</td>
</tr>
<tr>
<td>Peak flexor velocity</td>
<td>0.66</td>
<td>0.60, 0.72</td>
<td>38</td>
</tr>
<tr>
<td>Number of back moves/min</td>
<td>0.62</td>
<td>0.55, 0.68</td>
<td>38</td>
</tr>
<tr>
<td>Peak hand force</td>
<td>0.58</td>
<td>0.51, 0.65</td>
<td>38</td>
</tr>
<tr>
<td>Peak flexion</td>
<td>0.55</td>
<td>0.47, 0.62</td>
<td>38</td>
</tr>
<tr>
<td>Low loading (compression)</td>
<td>0.52</td>
<td>0.44, 0.60</td>
<td>37</td>
</tr>
<tr>
<td>Peak shear</td>
<td>0.35</td>
<td>0.25, 0.44</td>
<td>38</td>
</tr>
<tr>
<td>Cumulative disc compression</td>
<td>0.25</td>
<td>0.14, 0.35</td>
<td>38</td>
</tr>
<tr>
<td>Age</td>
<td>0.14</td>
<td>0.06, 0.23</td>
<td>65</td>
</tr>
<tr>
<td>Body Mass Index</td>
<td>0.15</td>
<td>0.07, 0.23</td>
<td>65</td>
</tr>
</tbody>
</table>

Table 6.15: Intra class correlation coefficients comparing the cases and the job-matched controls for measured BIOMECHANICAL variables. (In order of decreasing ICC value from top to bottom.)

Intra Class Correlation
In general, the level of agreement was good for the biomechanical factors, especially for the postural variables (ICC estimates near 0.8). Of the 12 variables examined by the ICC analysis, 7 are in the 0.6 to 0.8 range of "substantial" agreement, 3 others in
the 0.4 to 0.6 range of "moderate" agreement, with the other 2 falling to the 0.2 to 0.4 range of "fair" agreement. The mean value for 11 ICC coefficients calculated was 0.60, just at the cusp of "substantial" agreement. By comparison, as one would expect, worker-specific variables such as age and body mass index show very low correlation (ICC < 0.2) for the same group of 45 matched pairs examined. While not shown in the table, none of the mean differences (paired t-tests) for the variables were statistically significant (p<0.05).

Measuring Agreement for the Psychosocial Variables
Table 6.16 shows the results of comparisons between the pairs of cases and their job-matched controls on the self-reported psychosocial factors examined in the study.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>ICC</th>
<th>95% CI</th>
<th>Mean difference (%)</th>
<th>paired t-test p-value</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Job control</td>
<td>0.59</td>
<td>0.53, 0.64</td>
<td>4.3 (8.0)</td>
<td>0.04</td>
<td>64</td>
</tr>
<tr>
<td>Physical exertion</td>
<td>0.43</td>
<td>0.36, 0.49</td>
<td>0.2 (3.3)</td>
<td>0.27</td>
<td>65</td>
</tr>
<tr>
<td>Borg scale</td>
<td>0.42</td>
<td>0.34, 0.48</td>
<td>1.0 (11.8)</td>
<td>&lt; 0.01</td>
<td>65</td>
</tr>
<tr>
<td>Empowerment</td>
<td>0.40</td>
<td>0.32, 0.47</td>
<td>-0.9 (7.2)</td>
<td>0.02</td>
<td>65</td>
</tr>
<tr>
<td>Psychological demands</td>
<td>0.37</td>
<td>0.29, 0.44</td>
<td>3.0 (9.8)</td>
<td>&lt; 0.01</td>
<td>65</td>
</tr>
<tr>
<td>Supervisor support</td>
<td>0.21</td>
<td>0.13, 0.29</td>
<td>-0.2 (2.0)</td>
<td>0.66</td>
<td>63</td>
</tr>
<tr>
<td>Job self-identity</td>
<td>0.19</td>
<td>0.10, 0.27</td>
<td>0.9 (8.1)</td>
<td>0.04</td>
<td>64</td>
</tr>
<tr>
<td>Job dissatisfaction</td>
<td>0.18</td>
<td>0.10, 0.26</td>
<td>-0.1 (2.8)</td>
<td>0.58</td>
<td>65</td>
</tr>
<tr>
<td>Mastery</td>
<td>0.09</td>
<td>0.01, 0.18</td>
<td>0.3 (1.5)</td>
<td>0.5</td>
<td>65</td>
</tr>
<tr>
<td>Workplace social environment</td>
<td>0.08</td>
<td>0.00, 0.16</td>
<td>-0.2 (1.4)</td>
<td>0.56</td>
<td>65</td>
</tr>
<tr>
<td>Co-worker support</td>
<td>0.01</td>
<td>0.00, 0.07</td>
<td>-0.2 (1.7)</td>
<td>0.56</td>
<td>61</td>
</tr>
</tbody>
</table>

Variables are placed in order of decreasing ICC value from top to bottom. Negative sign for mean difference between case and control pairs indicates that cases had lower scores than controls. % mean difference calculated by dividing mean difference shown by the value of job-matched control mean. N refers to number of matched pairs in each analysis.

Table 6.16: Intra class correlation coefficients and mean differences in scores comparing the cases and the job-matched controls for SELF-REPORTED (psychosocial) variables, ranked according to ICC values.
Agreement between the cases and their job-matched controls for the self-reported (psychosocial) exposures was generally low, especially for the social support variables. Intraclass correlation coefficients (ICC's) ranged from near zero (for perceived coworker support) to almost 0.6 for job control. Of the 12 variables examined, 4 had "moderate" agreement (ICC between 0.4 and 0.6), 4 had "fair" agreement (ICC between 0.2 and 0.4), while the 5 remaining variables showed little or no agreement (ICC<0.2). The mean overall agreement for the 12 variables examined was 0.29, just under half that observed for the "objective" biomechanical measures. (This dropped to 0.26 if the two self-reported physical demands scales were excluded.)

The power of this analysis is greater than that for the biomechanical matched pairs since almost all subjects in the 65 pairs had complete self-reported psychosocial variable data, whereas only 38 pairs were available for the biomechanical agreement sub-study. The variables with the strongest agreement, with ICC values between 0.4 and 0.6, were those that could possibly be legitimately labelled as being the most work-related, or those that might be the least sensitive to the individual character of the worker, such as questions about how much control workers report they have over their job, or how physically demanding they find the work to be. Those factors showing the least agreement, with ICC values below 0.2, were questions about personal coping (mastery), job satisfaction and relations with coworkers. These may be fairly interpreted as being the most closely linked to the individual, and the least strongly linked to work.

The largest and most statistically significant differences were for the JCI psychological demands scale (cases rate scale 9.8% higher on average, \(p=0.003\)), the Borg scale, assessing demands of the job on the body (cases rate scale 11.8% higher on average, \(p=0.007\)), neither of which remained in the final multiple logistic model.
Sensitivity Analysis of Final Multiple Logistic Regression Model

To assess the impact of the proxy data on the results of the multivariable regression analysis, the final model was re-run excluding cases with substitute data. The results of this re-analysis are shown in Table 6.16, ranked according to the change (absolute value) in the OR. The only major differences between this analysis and the one including the proxy data are: 1) a moderate decrease in the estimated effect sizes for both peak shear force and job control, with the former losing its statistical significance; and 2) moderate increases in the OR for prior WCB and “over-education”. The other variables show very similar results to those observed with the full data set, indicating that use of proxies has not strongly influenced the study’s risk estimates. The model fit statistics also were largely unchanged, with the adjusted $r^2$ at 0.40, $c$ at 0.82 and p-value of the H/L chisquare at 0.34, all indicating that the fit of the model was unaffected by use of proxies.

<table>
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<tr>
<th>VARIABLE</th>
<th>OR</th>
<th>95% CI</th>
<th>% Change in OR*</th>
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<td>2.7</td>
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<td>Lower job control</td>
<td>1.7</td>
<td>0.8, 3.6</td>
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<td>Better co-worker support</td>
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<td>1.1, 2.5</td>
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<td>Better job satisfaction</td>
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<td>1.1, 2.4</td>
<td>+6</td>
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<tr>
<td>Higher perceived exertion</td>
<td>2.8</td>
<td>1.7, 4.9</td>
<td>-6</td>
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<tr>
<td>Poor workplace social environment</td>
<td>2.8</td>
<td>1.4, 5.8</td>
<td>+2</td>
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<tr>
<td>Higher peak shear</td>
<td>1.2</td>
<td>0.7, 2.0</td>
<td>-25</td>
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<td>Higher cumulative disc compression</td>
<td>1.6</td>
<td>1.1, 2.4</td>
<td>+6</td>
</tr>
<tr>
<td>Higher peak hand force</td>
<td>1.9</td>
<td>1.2, 3.1</td>
<td>+3</td>
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</table>

Table 6.17: Re-running final model without proxy data (80 cases, 125 controls).

b) Misclassification from Unreported LBP in the Controls

Slightly over one third (61/179, 34.1%) of the random controls could be classified
as having chronic unreported LBP, with a similar number defined as having acute LBP (57/179, 31.8%). None of these subjects had reported this LBP to the nursing station in the 90 days prior to enrolment in the study.

**Chronic LBP**

The results of the re-analysis of the final model excluding random controls with unreported LBP in the past year* are shown in Table 6.17. Once again, they are ranked by the absolute value of the change in the OR estimate from the model using the full data set (within the different risk factor groups).

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<th>VARIABLE</th>
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<th>% Change in OR</th>
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</thead>
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<td>Perception of being “over-educated”</td>
<td>1.8</td>
<td>0.8, 4.3</td>
<td>-18</td>
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<td>1.1, 2.7</td>
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<td>Lower job control</td>
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<tr>
<td>Higher Perceived exertion</td>
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<td>1.8, 6.0</td>
<td>+9</td>
</tr>
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<td>Higher peak hand force</td>
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<td>1.1, 2.7</td>
<td>+12</td>
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</table>

*a: "% Change in OR" indicates the effect of removing the controls with chronic unreported LBP on the odds ratio observed in final model when using the full (i.e. all subjects) data set. (OR estimates are based on the same interquartile unit difference used in the full model.

Table 6.18: Results of the final regression model excluding controls with chronic unreported LBP.

As one might expect, the importance of the variable assessing prior WCB claims for LBP increases sharply, doubling its effect size when the control group excludes anyone with a strong LBP history. Other points worth noting are that four of the

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* For the purposes of this analysis, unreported LBP was operationalized as either: i) an episode of pain in the past year that lasted for at least one week; or ii) having experienced 5 or more episodes of LBP of at least one day in duration in the past year.
terms previously statistically significant in the analysis of the unrestricted data set lose this statistical significance, suggesting either the effect of reducing the control sample size by a third (i.e. loss of power) or a possible effect of misclassification bias from a diminished case-control distinction in the analysis using all 179 controls. The four affected terms were peak shear, job control, over-education, and job dissatisfaction. Since the change in the effect sizes of these four terms is modest (all less than 20%), and all four terms had lower confidence intervals very close to 1.0 with the full data set, the loss of statistical significance is perhaps more of an indication of loss of study power than an indication of bias.

The effects for two of the three measured biomechanical terms, as well as the self-reported physical exertion scale, increased after removing the case-like controls, indicating that if inclusion of controls with unreported pain did bias the study results, the bias is likely to result in an underestimation for the effect of the physical demands of the job. The same could be said for the possible effect of including controls with chronic LBP on the workplace social environment scale. The increase in the OR for this variable once such controls were excluded possibly indicates the importance of chronic pain on the perceptions of the work environment.

**Acute LBP**

Table 6.18 shows the results of re-running the final regression model after excluding the 57 random controls with acute LBP.\(^d\) Once again, they are ranked by the absolute value of the change in the OR estimate from the model using the full data set (within the different risk factor groups).

Again, as expected, the odds ratios for most of the variables increase, with the exception of peak shear, job control and job dissatisfaction, all of which decrease

\(^d\) Acute LBP was defined as pain in the last week, based on the time of interview.
modestly. Again, the largest increase is for a history of prior WCB LBP claims (72%), and the variable assessing the workplace social environment (52%). Peak hand force and self-reported physical loading also showed some modest increase (19% and 7% respectively. These are very similar to the results seen above when excluding the chronic pain controls, which is probably an indication of the strong correlation between current and prior LBP.

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<tr>
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<th>OR</th>
<th>95% CI</th>
<th>% Change in OR</th>
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</thead>
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<td>Higher perceived exertion</td>
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<td>+17</td>
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<td>Higher co-worker support</td>
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<td>1.1, 2.5</td>
<td>+8</td>
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</table>

a: "% Change in OR" indicates the effect of removing the controls with acute unreported LBP on the odds ratio observed in final model when using the full (i.e. all subjects) data set. (OR estimates are based on the same interquartile unit difference used in the full model.

Table 6.19: Final regression model excluding controls with acute unreported LBP.

Summary
Some modest changes to risk estimates may have resulted from the decision not to exclude people with unreported LBP from the control group. In most cases, these changes indicate that the risk estimates derived from the final model may be under-estimates of the true effect of these variables on the reporting of LBP in the study site. However, the extent of this influence appears to be limited, and the main study findings are perhaps more referable to the full workforce than if one third of the potential controls had been excluded because of "mild" back pain.
# APPENDIX 6.1

## SUMMARY STATISTICS FOR BIOMECHANICAL VARIABLES

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<th>N</th>
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<th>Median</th>
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### SUMMARY STATISTICS FOR SELF-REPORTED VARIABLES

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## APPENDIX 6.2a

**Correlation analysis BIOMECANICAL - unrestricted sample size**

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**Pearson Correlation Coefficients / Prob > |r| under No. of Observations / Number of Observations**

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## APPENDIX 6.2b

Correlation analysis PSYCHOSOCIAL - restricted sample size (no missing data)

**Correlation Analysis**

11 'VAR' Variables: PSYCHOSOC SOC_ENV PHYSL_ENV PSYCHOSOC JOBWORTH EMPPOWER CONWORKER JOB_DIS REV_LATI SUPERVIS MASTERY

### Simple Statistics

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**Pearson Correlation Coefficients / Prob > |R| under HO: Rho=0 / N = 101**

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**Note:** All correlations are significant at the 0.05 level (2-tailed).
APPENDIX 6.3: Analysis of the Job Content Instrument

Because of its role in this study as the principal psychosocial data collection instrument, and because different versions of it are in use, the individual components of the scales and sub-scales of the JCI were submitted to an extensive statistical examination. This investigation was initially intended as a confirmatory factor analysis, to support the combinations of questions used in the standard JCI scales. However, because the preliminary bivariable analyses, together with correlation analyses and the close monitoring of the regression models identified some unexpected inter-relationships between model variables, further examination was felt to be warranted. The aims of this analysis were therefore to: i) establish the content validity of the instrument used to assess the main psychosocial risk factors examined in the study; ii) to assess the relationship between the JCI psychological job demands scale, and self-reported and directly measured variables that assessed the physical demands of work; and iii) to explore the possible inter-relationships between job control and the other risk factors that were examined.

i) Factor Analysis of the Psychosocial Variables

Rotated principal component factor analysis of the main psychosocial scales used in the study confirms that most scales have sound construct validity - i.e. the components of the various scales are correctly combined together, since the responses to the questions appear to be reasonably well correlated with one other. This conclusion is based on the results of the factor analysis shown in Table 1, where for each of the main variables included, the component questions load in the expected places and with moderately high loading values. This is especially true for the scales measuring job control (Factor 1) and supervisor support (Factor 2), which demonstrate very consistent factor loading patterns. However, as mentioned below, the exception is the component questions of the Karasek/Theorell psychological job demands scale, which do not load consistently with each other.
Table 1: Rotated Principal Component Analysis for Psychosocial Variables (See Appendix 5.2 for Study Questionnaire)

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<td>0.03319</td>
<td>0.00444</td>
<td>0.00444</td>
<td>0.00444</td>
<td>0.00444</td>
<td>Psychological Job Demands</td>
</tr>
<tr>
<td>H:3</td>
<td>0.76235</td>
<td>0.16378</td>
<td>0.06156</td>
<td>0.09519</td>
<td>0.07861</td>
<td>0.13879</td>
<td>0.04907</td>
<td>0.11889</td>
<td>(SPLIT Factor: 3 AND 9)</td>
</tr>
<tr>
<td>H:4</td>
<td>0.51905</td>
<td>0.05870</td>
<td>0.00026</td>
<td>0.23765</td>
<td>0.04319</td>
<td>0.00095</td>
<td>0.00095</td>
<td>0.00095</td>
<td>Supervisor Support</td>
</tr>
<tr>
<td>H:5</td>
<td>0.00185</td>
<td>0.00111</td>
<td>0.11987</td>
<td>0.07767</td>
<td>0.12787</td>
<td>0.01979</td>
<td>0.14574</td>
<td>0.06293</td>
<td>(Factor 2)</td>
</tr>
<tr>
<td>H:6</td>
<td>0.00429</td>
<td>0.06715</td>
<td>0.04393</td>
<td>0.09647</td>
<td>0.16320</td>
<td>0.21357</td>
<td>0.01675</td>
<td>0.02986</td>
<td>Coworker Support</td>
</tr>
<tr>
<td>H:7</td>
<td>0.01256</td>
<td>0.10256</td>
<td>0.17321</td>
<td>0.12697</td>
<td>0.13251</td>
<td>0.07610</td>
<td>0.09500</td>
<td>0.17587</td>
<td>(Factor 5)</td>
</tr>
<tr>
<td>H:8</td>
<td>0.13990</td>
<td>0.13990</td>
<td>0.01734</td>
<td>0.10531</td>
<td>0.18230</td>
<td>0.25988</td>
<td>0.07052</td>
<td>0.10978</td>
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</tr>
<tr>
<td>H:9</td>
<td>0.01734</td>
<td>0.07526</td>
<td>0.03710</td>
<td>0.08879</td>
<td>0.10413</td>
<td>0.09462</td>
<td>0.39998</td>
<td>0.00677</td>
<td>Job Self-Identity</td>
</tr>
<tr>
<td>H:10</td>
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<td>0.11544</td>
<td>0.22897</td>
<td>0.00094</td>
<td>0.02932</td>
<td>0.19580</td>
<td>0.18244</td>
<td>0.19735</td>
<td>(Factor 4)</td>
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<tr>
<td>H:11</td>
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<td>0.09638</td>
<td>0.13310</td>
<td>0.01662</td>
<td>0.14564</td>
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<td>0.08163</td>
<td>0.00373</td>
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<tr>
<td>H:12</td>
<td>0.12730</td>
<td>0.10603</td>
<td>0.10102</td>
<td>0.07995</td>
<td>0.12192</td>
<td>0.00781</td>
<td>0.04225</td>
<td>0.07537</td>
<td>(Factor 6)</td>
</tr>
<tr>
<td>H:13</td>
<td>0.11416</td>
<td>0.07523</td>
<td>0.13319</td>
<td>0.09024</td>
<td>0.14312</td>
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<td>0.05478</td>
<td>Dissatisfaction</td>
</tr>
<tr>
<td>H:14</td>
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<td>0.05660</td>
<td>0.01697</td>
<td>0.16516</td>
<td>0.20381</td>
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<td>0.07168</td>
<td>0.25710</td>
<td>(Factor 8)</td>
</tr>
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<td>H:15</td>
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<td>0.12896</td>
<td>0.00994</td>
<td>0.05270</td>
<td>0.08680</td>
<td>0.07077</td>
<td>0.04820</td>
<td>0.00269</td>
<td>(*) Not part of JCI</td>
</tr>
</tbody>
</table>

(Values in parentheses indicate less significant loadings. Bold text indicates characteristic loadings in bold. For a complete list of variables and their loadings, see Appendix 5.2.)
<table>
<thead>
<tr>
<th>Question</th>
<th>Chi square</th>
<th>p-value</th>
<th>Direction of Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>My job requires working very fast?</td>
<td>2.3</td>
<td>0.52</td>
<td>Cases report working faster more often</td>
</tr>
<tr>
<td>My job requires working very hard?</td>
<td>26.0</td>
<td>0.001</td>
<td>Cases report working very hard more often</td>
</tr>
<tr>
<td>I am asked to do an excessive amount of work?</td>
<td>7.6</td>
<td>0.05</td>
<td>Cases report excessive work more often</td>
</tr>
<tr>
<td>I have enough time to get the job done?</td>
<td>5.1</td>
<td>0.16</td>
<td>Cases report having enough time less often</td>
</tr>
<tr>
<td>I am free from conflicting demands that others make?</td>
<td>7.7</td>
<td>0.05</td>
<td>Cases report being free of conflicts more often</td>
</tr>
</tbody>
</table>

Table 2: Questions from the JCI Psychological Demands Scale

ii) The Self-Reported Demands Scales

The Karasek-Theorell psychological job demands scale is intended to measure the psychological stress associated with the work environment. As shown in Table 2, the recommended format of the psychological demands scale, as used in this thesis, is composed of five questions, each with four responses coded on a 1 to 4 scale. The sum of the five responses comprises the score for the variable.

The first three questions could be perceived as being more related to the physical job demands, such as the requirement for rapid, continuous motion. The other two questions could perhaps be addressing more cognitive-type demands, such as having enough time to get the job done. The split dimensions of this scale are evident in the results of the factor analysis shown in Table 1. The three terms that relate more to physical activity load with each other, as well as with the other questions from the JCI that address perceptions of work-related physical loading, such as the two questions from the physical exertion scale and a question about repetitive work from the job control scale. Contingency table analysis of the individual component questions of the psychological demands scale indicated that the questions describing physical demands showed the strongest association with case-control status (see Table 2). Thus, while most of the JCI scales seem to be
adequate for the type of work environment encountered in this study, the JCI psychological demands scale may be more a measure of work-related physical loading than of the psychological demands of work.

Two additional self-reported measures of the demands of work were used: the physical exertion scale of the JCI, assessing the degree of physical activity required on the job; and the Borg scale, which rates the demands of the job “on the body”. Based on the bivariable regression analysis described earlier, both of these variables were strongly associated with reported LBP, as was the psychological job demands scale. The overlap between these measures suggested by the factor analysis is further supported by correlation analyses, which showed good correlation between both of the self-reported physical demands scales and the JCI psychological demands scale, as evidenced by Pearson correlation coefficients of $r=0.62$ for the JCI physical exertion scale and the JCI psychological demands scale, and 0.45 for the Borg Scale and the psychological demands scale. (See Appendix 6.2b for the correlation matrix).

The inter-relationship between the demands scales was also apparent from their behaviour during the combined regression analysis. Whenever one of the terms measuring perceptions of work-related physical loading was included in a multivariable logistic regression model, the effect of the psychological job demands scale disappeared, as the correlation results would have predicted.

While correlations between the self-reported psychological and physical demands variables were reasonably high, as noted above, in general, the correlation of the psychosocial scales with the directly measured biomechanical variables was low. Only those directly measured variables that could be considered to be of a more global nature, such as average disc compression (which was derived by estimating disc compression over the full observation period using 10-15 second random sampling intervals) showed even moderately strong correlation coefficients ($r=0.52$...
and 0.45 for the JCI physical exertion and psychological demands scales respectively).

This may be an indication that most of the measured biomechanical variables are so narrowly focused on specific technical components of the physical demands of work that they can not be adequately addressed by simple questions put to the study subjects as part of a questionnaire. Consequently, the self-reported and the directly measured assessments of the physical demands of work may be addressing different aspects of these physical demands. For example, a subject’s perception of physically demanding work may relate more to moving around the factory on various errands and not specifically to tasks that may increase the biomechanical forces measured on the back. Alternatively, questionnaire responses to the questions about physically demanding work may relate more to the individual worker’s load “tolerance” than do the measured demands, which do not have a subjective “frailty” component built into them.

The low correlation between the self-reported and measured variables may be partly explained by the fact that the scales could be combined differently, to better reflect the factor analysis results. In such a “data-driven” factor formation, the two more cognitive-type questions in the psychological demands scale (#4 and #5 in Table 2) would be separated out to their own sub-scale, and the remaining JCI questions that load together, those from the physical exertion scale and the remaining demands scale questions, would be combined to form a new pair of sub-scales. Bivariable regression results of these two new sub-scales show a strengthened effect for the new physical demands variable and suggest that the more cognitive work demands are less important in this study environment.

Although these results might suggest that a modified (data-driven) form of the JCI psychological demands scale could have been used, post hoc, in this study, the standard forms of the JCI scales were retained because of their widespread use and
the absence of an *a priori* reason to modify them. Further development work of the JCI psychological demands scale may be warranted, especially when it is to be used in industrial settings. Other researchers have recently voiced similar criticisms of this instrument.²

**iii) Job Control**

While the strong bivariable effect observed for the psychological demands scale disappeared, once other factors were taken into account in multivariable regression, the reverse effect was seen for job control. Its bivariable results were clearly non-significant, with virtually no difference observed between the mean level of job control for cases and controls (57.1 versus 56.5 respectively, *p*=0.79). Yet when entered into multivariable logistic regression analyses that controlled for measured biomechanical loading and perceptions of loading, job control demonstrated a moderately strong "protective effect", indicating that higher levels of control could substantially reduce LBP risk.

The results of the rotated principal component factor analysis for job control (see Table 1) indicate that all of its individual component questions are well correlated with each other, with all but one of them loading strongly on the same factor (this one question had a complex loading pattern). No other questions loaded strongly with the control scale.

In an attempt to determine which of the other risk factors from the final multivariable model were most likely responsible for the observed change in the job control regression parameters, a detailed regression analysis was performed. Selected variables were added to the "control" term individually, while the regression output was closely monitored as each variable was added. The factors identified as having the largest impact on the regression parameters for job control were the measured biomechanical terms, especially peak shear and peak hand force. To further examine this relationship, the data lines were printed and the pattern of
control and physical demands observed. From scatter plots of "control" by the "physical demands" terms, there is some suggestion that subjects with higher levels of job control also tended to have higher physical demands. This is also suggested by the weak correlation between job control and peak shear and peak hand load (r=0.32 and r=0.36 respectively). This relationship is contrary to what might be expected, since one might expect that higher job control would lead to "easier" jobs rather than more demanding ones. Further investigation of this interesting relationship is planned.

Summary
The format of the psychological demands scale used for this thesis was five questions with four intensity-based grading response categories. Other formats have been used, including a "Swedish" variation, with more quantitative response categories. Based on the information presented above, the JCI psychological job demands scale, as used in this thesis, may be more of a measure of work-related physical loading than the psychological demands of work. This finding may be a consequence of studying a work environment with relatively higher levels of physically demanding work than have been used with the JCI in other investigations. It may also be a consequence of using an instrument that was specifically designed for cardiovascular disease research, and thus may need special adaptation for studies of musculoskeletal outcomes, which necessarily have a particularly strong focus on the physical demands of work.

Notwithstanding the exception discussed above, based on the results of the analyses presented here and in the main text of the thesis, the components of the JCI subscales appear to accurately measure the constructs they were designed for. Finally, job control appears to be an important factor in reported LBP etiology once the physical demands of work are accounted for.

DISCUSSION

Introduction

There are two main goals for this discussion: i) to demonstrate, by reviewing the methodological strengths and limitations of the study, that the study met its main objective of identifying work-related risk factors for LBP, and that these findings are robust, and not likely to due to chance or bias; and ii) to outline the scientific merit of this thesis with regards to its contribution to the current knowledge base on the etiology of occupational LBP as well as its potential utility for primary prevention efforts aimed at reducing the incidence of LBP in the workplace. The discussion is structured so that it deals with each of these objectives in turn.

Part I: Methodological Strengths and Limitations of the Study

There are a number of factors resulting from the design of the study, the selection and accrual of the subjects, and the collection and analysis of the data, that could either strengthen or weaken the robustness of the study’s main findings. A summary of some of these key influences is presented below, beginning with the strengths of the study.

A) Strengths

The main strengths of the study are shown below, in Table 7.1. This list of positive study attributes, although by no means exhaustive, is meant to reflect how this thesis has differed from other LBP etiologic research efforts. Since many of the criticisms of prior research have focused on the limited scope of the exposure assessments, problems with the methods used to collect the exposure data, particularly for the physical demands of work, and problems with defining the condition, the list shown in Table 7.1 specifically addresses these main concerns. The table is then followed by a brief discussion of the main points.
1. A comprehensive approach was adopted for exposure assessment, focusing on work-related biomechanical and psychosocial risk factors measured at the individual worker/job level, using the “best available” methods, while controlling for individual worker characteristics.

2. Use of directly measured biomechanical risk factors limit concerns about recall bias when assessing the physical demands of work.

3. Inclusion of a third study group, the controls matched exactly to the cases by the job being done at the time of the case report of LBP, allowed for substitution of data for cases without their own biomechanical data and an assessment of potential recall or “rumination” bias for self-reported (psychosocial) variables.5

4. Inclusive case definition of workers with and without WCB claims, and control definition did not exclude the 30% of workers with unreported LBP (in the year or week prior to the interview).

5. Accrual of newly incident cases of reported LBP with controls chosen at random from a well defined study base using incidence-density sampling (controls for plant-level changes in exposure over time and permits OR estimates to be used as direct estimates of RR).

Table 7.1: Key Methodological Strengths of the Study

Comprehensive Assessment of Exposure

Based on the literature review included in this thesis, and on discussions with other occupational health researchers focusing on musculoskeletal problems, the study presented in this dissertation used the most comprehensive exposure assessments yet attempted to examine work-related risk factors for LBP. While some studies have collected considerable detail on the physical demand of work67, they have not combined this with an equally thorough assessment of the suspected psychosocial risk factors for LBP. Having data on both types of risk factors, as well as information about worker-specific characteristics, permits a better estimation of the
 independent (unconfounded) contribution of putative risk factors to the etiology of LBP. This study also benefits from having a detailed clinical profile of all subjects because of the twining of the etiologic and prognostic components of the overall study. Indeed, one of the purposes of combining the two studies was to have reciprocal data available - i.e. clinical data for the etiologic study, and work-related exposure data for the prognostic study.

**Direct Biomechanical Measures**

What also separates this study from other research efforts is not only the scope, but also the detail of the exposure assessments used. This is particularly true for the collection of the biomechanical data, which focused on measuring the task-based details of the physical demands of the current job for each subject. The assessments were designed not only to use the best available methods to collect risk factor data on peak and cumulative loads, but also to help further the development of new and better assessment methods, since so few large-scale studies have directly measured work-related biomechanical demands. In some instances, the same construct, e.g. disc compression, was measured in several different ways, with varying degrees of complexity, accuracy and cost. This "common metric" approach to exposure assessments of physical work load in epidemiologic studies, while not central to this thesis, gives the overall IWH study data set a unique and important value. The details about this common metric approach, using the example of disc compression, have been recently published.⁸

Based on previous reliability studies, these direct measures are considered to be the best way to examine the physical demands of work.⁹ Self-reporting was found to be biased, at least for the kind of questions that could quantify occupational ergonomic exposure, and thereby be of use in developing primary prevention efforts. Questions about specific components of tasks, like lifting or other activities,
were especially unreliable, while more generic assessments of the overall job demands were found to be less so.  

Direct measures of the psychosocial work environment were not possible at the time of the design of the study, nor have they been reported in the literature since, although a number of studies regarding the association between stress and musculoskeletal pain are beginning to emerge. New evidence is also emerging about direct biological effects of work-related psychosocial stress that may eventually lead to biological markers for monitoring exposure to workplace psychosocial stressors. This is perhaps one of the future areas of research that may prove most useful in occupational musculoskeletal research. However, one of the difficulties in developing direct measures may be the presence of at least two dimensions to psychosocial variables - one emanating from the individual, the other from the work itself or the work environment. The ability of an expert to “assign” a value for how an individual perceives his/her work environment, without asking him/her, is questionable. Similarly, the correlation between what a person says and what a putative biomarker shows may be low because “perception” may not accurately reflect “reality”.

Job Matching
In the original design of the study, the job-matched controls had two purposes: i) to give some additional insight into purely worker-related risk factors since the strongly job-related factors, especially the physical demands of work, would be controlled for by the matching; and ii) to provide biomechanical data for cases who could not be assessed. Because we were able to recruit only 65 controls matched to one of the cases on the exact job the case was doing at the time of reporting their injury, a full worker-related risk factor analysis of the job-matched controls and cases was not possible. Consequently, the main purpose of the job-matched controls
in this thesis was to provide substitute data for cases as required. With the limited data available, the analyses examining possible bias from use of post-injury data were therefore restricted to examinations of agreement (intra-class correlation) between the cases and job-matched controls on the key study measures, including both the biomechanical and psychosocial factors. In other words, did people doing the same job experience the same levels of biomechanical risk factors and did they have similar perceptions of their work environment?.

Almost 20% of the 105 cases with biomechanical data were assigned these data from a job-matched control. The main benefit of this strategy was the provision of a clear increase in the study power, since the sample size for a combined biomechanical-psychosocial risk-factor model would have been further reduced by these 20 subjects without the availability of the proxies. (The validity of the proxy data strategy is discussed in the next section, under reliability/validity in the “Limitations of the Study”).

The analysis also compared the psychosocial exposure data for cases and job-matched controls to assess the extent of possible recall bias affecting questionnaire responses collected from cases after they reported their injury. As presented in Table 6.16 in the Results (page 126), agreement between the cases and their job-matched controls for the self-reported (psychosocial) exposures was generally low, especially for the social support variables. Intra-class correlation coefficients (ICC’s) ranged from near zero (for coworker support) to a high of 0.6 for job control. The overall agreement for the psychosocial variables examined was just under half that observed for the “objective” biomechanical measures, indicating that these variables are likely susceptible to influences other than simply the tasks involved with the job. In other words, the variation in responses suggests that people doing the same job need not have the same perceptions about their coworkers or their work
environment. These perceptions are clearly a consequence of a series of complex, undefined inputs, with work being only one aspect.

The variables with the best agreement, with ICC values between 0.4 and 0.6, were those that could possibly be legitimately labelled as being the most work-related, or those that might be the least sensitive to the individual character of the worker, such as questions about how much control workers report they have over their job, or how physically demanding they find the work to be. Those factors showing the least agreement, with ICC values below 0.2, were questions about personal coping (mastery), job satisfaction and relations with coworkers. These may be fairly interpreted as being the most closely linked to the individual, and the least strongly linked to work.

Analysis of the mean values of the differences in responses by the cases and their job-matched pairs, by paired t-tests, demonstrated several variables with significant pair-wise differences, most of which indicated that the case tends to report worse levels than the person doing the same job, who has not recently reported LBP. However, all but one of the individual variable paired t-test differences were less than 10% of the control group mean for these variables, indicating that the extent of this potential recall bias was limited. Therefore, there does not appear to be any evidence of strong recall bias by the cases, at least for those self-reported variables remaining in the final model of the main risk factor analysis, since workers in the same job give similar responses to the more work-related questions. The extent of the bias appears to have been limited where present. However, given that the

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a Paired t-tests can be misleading when used for agreement studies. If used in the absence of other tests, such as scatter plots and ICC calculations, a non-significant paired t-test can be incorrectly interpreted as indicating agreement, when in fact random error can lead to the high p-value. When used in conjunction with these other tests however, they can give an indication of systematic differences.
observed differences could also be due to real differences between the cases and the job-matches, these conclusions on the extent of recall bias need to be viewed with some degree of caution. It is difficult to infer the existence (or absence) of recall bias based solely on the analyses described above. For example, simply because cases and controls perceive their work environments differently does not mean that this difference is due to biased responses by the cases. Although they were compared with people doing the same job as them, this matching was based on criteria referring to the physical demands and output of the job. The jobs could be still different in ways that such matching could not control, such as the effects of different coworkers and/or supervisors. As with any cross-sectional comparisons, it is not possible to determine if these differences are a consequence of reporting back pain to the workplace, or they are a contributing factor to the onset of the report.

Subject accrual
With a total base population of over 10,000 eligible employees, the study site easily provided a broad exposure diversity, even with its high level of automated assembly line work. In addition to those directly building or servicing the new vehicles, a substantial fraction of the workforce in both plants was engaged in non-assembly line work, including regular maintenance and skilled trades. Randomly sampling the controls from the study base created a comparison group that was truly representative of the source of possible cases, and thereby permitted the estimation of study population risk levels for the factors being examined.\textsuperscript{15}

Before the study started, it was recognized that LBP was a relatively common event that would likely have a high prevalence in a setting such as an automobile assembly complex. This would have been particularly true if a long time frame had been chosen for a case definition - e.g. “any LBP in the last year” - which was a
factor in determining the final criterion used for eligible incident cases - i.e. "no report of LBP to the nursing stations in the previous 90 days". It was also recognized that some people might remain at work without reporting their LBP to the nursing station. This combination of high prevalence and occult LBP meant that it was possible that control subjects could report LBP on examination by the study team, even if they had not reported it to the nursing station in the last three months. Previous studies in similar work environments had suggested that over 50% of the workforce could be excluded if current or recent LBP was an exclusion criterion. To keep the results of this study as generalizable as possible, such subjects were not excluded from the control group, despite the potential for misclassification bias, caused by a diminished case-control distinction, potentially diluting the study’s final relative risk estimates. (Since detailed clinical data was collected on all subjects, examining the effect of this inclusive control definition was possible. This is examined under point #5 of the Limitations to the Study, since the issue can be viewed as both a strength and a possible weakness.)

Other possibilities to accrue cases outside of the workplace, such as through the offices of local family doctors or chiropractors, were rejected because of anticipated logistical problems and the extra expense that would be required. From discussions with the workplace parties, it was also determined that most, if not all, work-related LBP would be reported to the nursing stations. Although not all of these nursing station reports resulted in a WCB claim being filed, to be eligible for either workers' compensation benefits or the company's own private insurer health-benefit plan, employees must report health problems to these nursing stations.

Using data directly from the WCB was deemed unfeasible for a case-control study of LBP because of the lag time from filing a claim to its being accessible in the WCB database and because full data were available only for claimants requiring work
absence (lost time). Use of routinely collected WCB data to accrue cases would likely prevent the collection of cases with relatively recent LBP. Newly reported cases were preferable since we wanted to minimize any influence that either disability and/or the filing of compensation claims might have had on subjects' questionnaire responses. The workforce might have also viewed a WCB-claims-only study as being part of a "witch-hunt" to identify fraudulent WCB claims. Finally, if cases were, by definition, restricted to WCB claimants, the study would have excluded the large proportion of subjects with LBP who do not file claims in this setting. It was therefore concluded that self-reports to the nursing stations were the most comprehensive and systematic source for identifying new cases of LBP, including those that had the potential to lead to occupational disability.

**Other Advantages**

There are several other less tangible strengths for this study, such as the absence of any direct financial commitment from the two main stakeholders, which hopefully prevented the perception that the study was biased, from the outset. As well, subjects were usually interviewed for the study within a week of enrolment, thereby possibly limiting the affect of the injury on cases' perceptions of work.

The assessment of biomechanical exposures was done while the subjects did their normal, everyday jobs, not as part of a study "mock-up" (job simulation) procedure. These assessments were typically done after the baseline in-home interview, usually about one month after enrolment. The one-month average delay between case enrolment and the assessment of job demands, while required mainly for logistical reasons, also meant that, when assessed, most cases would have been out of the acute pain phase of their condition, as most "ordinary" LBP resolves itself within two weeks of onset. Most subjects were therefore observed performing work in the "usual" manner, rather than in a style required to accommodate LBP.
Finally, a wealth of information was collected on the clinical features of the subjects' LBP, which permitted the evaluation of the severity of the LBP amongst the cases, as well as estimation of the prevalence of LBP among the random controls.
B) Limitations

Some of the more important potential limiting factors in the interpretation of the main findings of the thesis are outlined below in Table 7.2.

1. Case-control designs are often not regarded as providing strong evidence of cause-effect; thus results could be viewed skeptically.

2. Despite finding a number of statistical associations, the small sample size may have still overlooked important risk factors.

3. Only limited reliability and validity information was available for most of the data collection instruments used, since no other studies had tried these specific assessments in LBP studies before.

4. Inclusive case definition involving reporting, not just having LBP, may mean that results are not generalizable outside of the study setting, since reported LBP may be too contextual.

5. The study participation rate may be low, especially for capture of WCB claimants. The two-step accrual, with nurses as “gate-keepers”, prevented direct access to potential subjects and may have reduced participation, although “slippage” was most likely random.

Table 7.2: Key Methodological Limitations of the Study

Case-Control Design

Some of the features of the design of this study were already discussed under Chapter 4. Presented below is a discussion of how the design may have impinged
upon the integrity of the study’s main findings.

Since it is impossible to justify, on ethical, scientific or logistical grounds, the random allocation of hundreds of workers to jobs with varying levels of high and low physical and/or psychosocial demands, researchers trying to understand the complexities of LBP etiology are limited to observational studies.\textsuperscript{17} For some, the best choice might initially be a cohort study, since these are generally perceived to most closely resemble the randomized trial paradigm, while case control studies are generally accepted to be more prone to the many biases affecting epidemiological studies.\textsuperscript{17,18}

In a workplace prospective cohort study of LBP, a large group of healthy (LBP-free) subjects would be assembled, and their work environment measured before they develop LBP. In order to link current exposure with current LBP status, this cohort would then have to be closely followed over time to monitor the occurrence of LBP and any changes (from baseline) in exposure to the study risk factors. The chief scientific advantage of a cohort study results from the exposure profile of the subjects being recorded before back pain develops. Thus the link between exposure and outcome is more readily apparent than in studies using retrospective exposure assessments. The information provided by subjects in a cohort study is therefore normally regarded as being less prone to information bias, particularly recall or ‘rumination’ bias resulting from the injury/disease process.\textsuperscript{5,18}

For etiologic studies of LBP, these apparent advantages of cohort studies may not be so readily achievable\textsuperscript{17}. The potential for the enhanced rigour of cohort studies depends upon the study’s ability to carefully and accurately monitor putative risk factors being over time, or, if the assessments are not to be repeated, that any change in exposure after the initial assessment is not relevant to the outcome. While cheap
and accurate exposure assessments may be possible for some occupational exposures, such as ionizing radiation, this is clearly not the case for putative risk factors for LBP. No measurement tools are known to exist that would permit the collection of data suitable for repeatedly and accurately assessing the relevant exposures of a large workforce, given that job biomechanical demands and psychosocial attributes often change frequently in modern industrial settings.

Based on the short durations of specific job tenures observed in this study, it is very unlikely that "once-only" baseline measures in a cohort study would accurately reflect the subjects' true exposure at the time of reporting LBP, especially for the physical demands of work. The rate at which workers change jobs or the jobs themselves change is largely the result of the speed with which the manufacturing process changes in a large and modern automobile production facility, since it must respond to the changes in the market demand and economic pressures (e.g. "just-in-time" delivery of parts) for its products.

Therefore, these frequent changes in jobs increase the likelihood for misclassification of exposure. The resulting information bias may partly explain why the largest study on the etiology of LBP, a three-year prospective cohort study of Boeing airplane assembly workers\textsuperscript{19}, did not find an association between measured workplace physical demands and the reporting of LBP (filing a workers' compensation claim), while this thesis, using a case control study design, with more sophisticated assessment procedures on newly reported cases of LBP, has clearly found an association between the two.

The discrepancy between these two studies may also be partly explained by differences in the assessment strategy used, with this thesis relying on the measurement of individual workers at their own usual job, while the Boeing study
used group-level assignment of exposures. The problem with this strategy was illustrated in this study when an analysis of distribution of work done according to job titles showed almost identical distribution of job categories between the two groups. This lack of distinction using a group-level measure illustrates the problem of relying solely on such surrogates for actual measurements of job demands, since almost all of the measured demands of work reported in this study were significantly heavier for cases than they were for controls. This is a strong indication of the lack of utility of error-prone exposure variables in etiologic studies of LBP, as has been suggested elsewhere.\textsuperscript{2,20}

**Study Power**

The fact that the study was able to detect eight statistically significant risk factor associations in the final multiple logistic regression model, most of which had OR's close to 2.0, clearly shows that the study had sufficient statistical power. Getting workplace parties to agree to act on risk factors with lower OR's, which would necessitate a study with a larger sample size, would be very unlikely. In addition, the cost of the job assessment methods described in this thesis, both financially and logistically, were too prohibitive to consider any significant sample size increase.

It is worth noting here that etiologic epidemiological studies rarely account for much more variance than the final model presented for this study, with an adjusted $r^2$ statistic indicating that over 40\% of the study variance could be accounted for by the model. Even disease models for conditions like CVD, that have been studied for decades, rarely "explain" so much.\textsuperscript{21,22} In the Boeing study, the only large scale prospective cohort study of occupational LBP to date, and thus the only study acts as appropriate benchmark for the prediction of LBP, the final multivariate statistical model for the study accounted for just over 10\% of the LBP reports observed. The higher "explanatory" power of the thesis model is perhaps a vindication of the
expense and effort spent on the comprehensive nature of the exposure assessments used to assess both the biomechanical and psychosocial work environments.

**Limited Measurement Error Estimates**

The type of biomechanical assessments used in the study have not been fully validated for use in large-scale epidemiological research. These assessment procedures have been pilot-tested in the field, which included identification of logistical problems as well as a test of the reliability of these measures. However, most of the individual components of these measures have been validated in the laboratory or small-scale pilot studies in the workplace. Some doubt may remain about their ability to accurately capture the actual physical demands of the jobs being measured. This is particularly true for subjects with non-assembly-line jobs - i.e. those that do not have clearly definable job cycles and/or repetitive tasks.

Thus even though these biomechanical assessments are the state-of-the-art, and are considered by most experts to be clearly preferable to self-reported questionnaires (which have previously been shown to be highly prone to error), it is not possible to be sure they provide an accurate measurement of physical loading. The error associated with these measures is most likely to be non-systematic (i.e. it applies equally to cases or controls). The most likely effect of this error will be to reduce the study power for these exposures. This would certainly be a concern, given the small sample size of the study, had no associations been observed (i.e. the results had been "negative").

Accurate estimates of the error associated with the instruments used in this study

\[ \text{\footnotesize \textsuperscript{b}} \] Although tests of these measures were not part of this thesis protocol, the measures are being examined by the biomechanics team at the University of Waterloo. Some early results are starting to appear.(Neumann et al., 1996)
were not possible, particularly for the directly measured biomechanical variables, largely because these measures were considered "gold standards" based on laboratory studies, and thus validity in workplace settings has never been established. For some measures used establishing "in vivo" validity is not possible, given that some of the biomechanical model assumptions are not measurable in living subjects.²³

Despite these qualifications, one of the ways that this thesis could get some indication of measurement error was a comparison of the cases with their job-matched controls. This comparison was previously mentioned in the discussion in relation to recall bias in relation to the psychosocial measures, was also described in the chapter 6, where the observed agreement between the cases and their job-matched controls indicates that misclassification error, the most potentially worrisome result of measurement error, is not likely a major concern for the results of this study.

The "good" level of agreement (ICC values averaging 0.6) reported for most of the measured biomechanical exposures in the Results chapter (Table 6.15) was to be expected, given that the matching criteria used were primarily based on the physical tasks and output involved with the job. This observed agreement, still however, provides evidence of the validity of the biomechanical assessment methods, since the results imply that people doing the same job have very similar measured exposures, irrespective of their injury (i.e. case or control) status. The good level of agreement observed for these measures, between the cases and job-matched controls, also supports the strategy of using proxy biomechanical data, from job-matched controls, in the main risk factor analysis for cases without their own biomechanical data.
However, it is worth noting that none of the ICC coefficients were above 0.80, a level indicative of excellent, or near-perfect agreement. This suggests either the measures have some inherent level of random error, or that people doing basically the same job may actually be exposed to slightly different physical demands, at least in relation to the lumbar spine. Therefore, while the results of the analyses presented here suggest that exact job-matching does a good job of controlling for the physical demands of work (as estimated by biomechanical measures examined here), the fact that the observed agreement was not higher suggests that controlling for these measures on anything less that exact matching, such as job title, would most lead likely to a higher level of misclassification. This increased error could dilute any true associations, perhaps to the point where the claim of “controlling for the physical demands of work”, when using anything less than exact job matching or direct measurements, may not be valid.

Interestingly, while the overall level of observed agreement was good, the two biomechanical variables with the lowest agreement are peak shear and integrated compression, two of the terms that remained in the final multiple logistic regression model presented earlier. If the difference between the cases and their job-matched pairs is real, then this low ICC value may be explained by peak shear and integrated compression being more susceptible to the way in which the work is performed by individuals or by the individuals themselves, than are the other measures. For example, estimates of peak shear may also be affected more by the body weight or load handling than other calculated variables, such as peak compression. Integrated compression on the other hand, depends to some extent on the way people wait between their cycled job tasks, and the way this waiting is done (e.g. supported posture, stooping, etc.) is likely more susceptible to individual worker discretion than the work tasks themselves.
If the low agreement is from error, then two main factors may be at play. This is the first time these variables, and especially peak shear, have been measured in a large-scale study, and therefore the lower agreement may indicate a problem with the measurement itself or with the computer modelling methods used to derive the exposure estimate. Both peak shear and integrated compression require a number of data inputs to be entered for the biomechanical models (which themselves require a number of assumptions) in order to produce the estimated values used in the final analysis. The three-step procedure used for calculating these two variables - recording the video tape, selecting the frame (or frames) best representing the task (or tasks) being examined, and then entering the other required inputs for the biomechanical model (gender, weight, height, force in hands, etc.) - may result in lower agreement because of the increased room for error. However, it should be noted that the peak compression estimates showed better agreement than either peak shear or integrated compression. This variables estimates were derived using the same three-step procedure, although the biomechanical models used to derive peak compression have been in use longer, and thus may be better developed.

Further work needs to be done to explain this finding.

The low agreement for integrated compression may also be a consequence of its being an index variable, derived by the addition of the combined disc compression from three work components - dynamic (working) loads, static (holding) loads, and waiting loads (often seated). The contribution from each of these three video images were weighted according to the proportion of the overall shift spent in each category, based on the portion of the working shift they were observed in the field. A factor analysis of the three terms used to create the integrated compression scale, using the data from the cases and the unmatched controls, indicates that two of the variables, task and static, load better than the third, waiting, suggesting that combining the three variables into a single index may have increased the error
associated with the index variable as used. However, since this error would be random, the association between integrated compression and LBP observed in the main risk factor analysis is likely under-estimated, rather than over-estimated by the data.

Finally, rotated principal component factor analysis was used to explore the inter-relationships between the individual questions used in the different constructs found within the Job Content Instrument. The results of this analysis, presented in Appendix 6.3 of the Results chapter, indicates that there was at least good construct validity for most of the psychosocial scales used, with the component questions of the scales loading strongly where expected. The one exception discussed was for the psychological demands scale, which seemed to have two components: one behaved more like a measure of perceived physical demands; the other assessing a different construct, possibly related more to cognitive-type demands of work. The lack of an effect for the psychological demands scale in this study could therefore be a direct consequence of the combination of this misclassification error from combining two different constructs in one scale, and the inclusion of other physical demands measures in the statistical models used.

Thus, the results of these measurement error analyses indicate that there is reasonably good agreement for measures of the biomechanical exposures among pairs of people doing exactly the same jobs. This supports the use of proxy biomechanical data from someone doing the same job as a case, when the case data were unavailable. The results also indicate that the injury process does not appear to have produced any serious bias for either these variables, or the self-reported (psychosocial) variables.
Participation Rates

The original plan was to accrue 150 cases and an equal number of random and job-matched controls. Overall, accrual was slower than anticipated, especially in the last few months of field work. A number of constraints appeared that may explain this slow accrual, including some typical to any epidemiological field work, such as refusals, and others specific to working in occupational settings. Accrual was particularly hampered by production adjustments in the two car plants during the first nine months of the study. These problems completely prevented recruitment of any subjects from the car plant, effectively reducing the study base to 30% of its original size during the line adjustment period.

Based on interviews with the plant nurses, there does not appear to be any systematic reason for the slower-than-expected accrual, so that biased case intake is considered unlikely. Data collection ceased before the expected intake of 150 cases was reached largely because of the great expense associated with keeping the study running when new cases were being accrued at such a low rate.

The adjusted participate rate in Table 6.1 of the Results (60% for the cases, 36% for the random controls) represents a reasonably good response rate for an occupational study of LBP. By comparison, in the Boeing study, of the 4030 workers contacted about the study, 3030 (75%) "agreed" to participate, with 1569 workers (54% of those agreeing or 39% of all workers contacted) actually returning the study questionnaire. Of the 324 LBP reports recorded by the nurses specifically for the study, 268 (83%) agreed to be contacted further about the study, with 86% of the eligible workers agreeing to participate. A significant number of subjects (cases 22, or 14%, random controls, 28, or 16%) eventually withdrew from the study after initially agreeing. This may be partly explained by the large time commitment required of study subjects.
We were not able to directly recruit subjects as they entered the nursing station for treatment. Instead, attempts were made to help the plant nurses keep track of potential subjects, by producing special log sheets and making daily calls to the various stations to collect names of potential cases. Based on these activities, and from informal discussions with the nurses, it is known that at least some potential cases were not informed of the study, thus partly explaining the slower than expected accrual. While the "capture" of cases at the nursing stations may not have been complete, in the opinion of the nurses at least, there was no systematic bias in who was informed about the study and who was not. Rather, the main reason for not asking a worker to participate appears to have been the heavy case load of the company nurses, who were responsible for all injuries and illness in the huge plants.

Although back pain was the largest single category of work-related problems at this study site, it still accounted for only a small percentage of the total nursing station visits, since many of these visits were not for work-related conditions (e.g. flu infections) and many others were for basic first aid (e.g. minor cuts or abrasions).

Since the IWH has legally sanctioned special access to WCB databases, it was possible to make a basic comparison of the study workers who filed a WCB claim for LBP with other workers filing WCB claims for LBP during the study time period whom the study was not informed about. The male:female ratio of the unrecruited WCB claimants from our base population was the same as that observed for the WCB claimants reported to the study, as were the mean age, duration of lost-time from work and the years of experience at their current job, all of which suggest an absence of systematic bias in our case selection process. The lack of any difference with the variable assessing claim duration is an especially important indicator in this regard, as recent work has suggested that there are major differences between

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c Poster campaigns, plant newsletter articles, and lunchroom "brown bag" sessions were also used to help solicit support and awareness for the study among the workforce.
workers with long duration claims compared to those with short duration claims, that reflect particularly, the psychosocial aspects of work in addition to “case severity”.25

A second aspect of the WCB claims of interest to the study is that the proportion of cases who filed WCB claims with lost-time wage-replacement (2/3 lost-time, 1/3 no lost-time) was virtually identical to that observed for the province of Ontario as a whole in 1995 the last year with available data16. The same two-thirds lost-time proportion was observed for a series of cases examined in the company’s records for the year prior to the commencement of data collection. This provides further evidence that the cases were likely a random sample of the full set of new LBP cases attending the nursing stations at the study site, rather than a biased, unrepresentative sub-set.

Finally, comparing subjects enrolled in the study to the rest of the eligible GM-Oshawa workforce not actively participating was difficult since there was very little comparative data available, other than some very basic demographic information on age and sex. A study on working conditions in the Canadian automobile manufacturing sector, sponsored by the CAW, reported age and sex characteristics for the Oshawa plants that were very similar to what we observed - i.e. the workforce is about 90% male, with 40 years as an average age.27

While the modest participation rates reported for this study may leave room for concern about selection bias being a potential problem, at least in the interpretation and dissemination of the results, if not in their validity, a number of steps were taken to examine this issue analytically and none indicated that the subjects are a biased subset of the base population. As well, cases were recruited through the plant nurses, who have a good relationship with the workers, especially since they
are unionized themselves, and thus are not viewed with suspicion as part of the management structure. Finally, interviewers and assessors were nominally blinded to the case/control status of the subjects, although due to the intimate nature of the interviews and assessments, this step may not have been entirely effective.

**Back Pain Definition**

Some critics of the study may perceive the use of "reported" pain for a case definition as being too contextual or specific to the study work site to be generalizable as "real" LBP. This argument assumes that reported pain is the same as unreported pain, and that therefore, this study is more of an examination of the risk factors for attending the occupational health clinics rather than for the occurrence of LBP itself. This view is not supported by the review of the clinical findings of the study subjects, which clearly showed a distinction between the study groups on all relevant acute pain indices (see for example tables 6.6-6.8 and Figures 6.1 and 6.3 of the Results, showing data for the Roland scale, the physical exam and the pain-related scales of the SF-36).

Indeed, the study was deliberately designed to examine the risk factors for reporting LBP in the workplace rather than its presence *per se*, as the former was regarded as a more likely indicator of future disability. The ubiquitousness of LBP, combined with the impracticality of constantly surveying the workforce to identify new unreported cases, discouraged an examination of risk factors for any definition of LBP less "severe" than the reported LBP definition used here. Since many controls working with unreported LBP were expected to be enrolled in the study, the extent to which any misclassification may have biased our results could be readily assessed. The results of that sensitivity-type analysis, outlined in Table 6.17 of the Results, suggested no major impact of excluding these controls from the multivariate risk factor analysis, apart from the expected increase in the association
between prior LBP and the newly reported LBP, and a reduction in study power resulting in loss of statistical significance for some of the effect estimates. The fact that almost one-third of the random controls reported having some form of LBP in the last week (other than that reported to the nursing station) suggests that not excluding such workers was the correct design strategy. Otherwise, the utility of a study's findings for the development of workplace primary prevention efforts to reduce the incidence of LBP would likely have been seriously compromised, based on the use of such an unrepresentative comparison group.

**Part II: The Scientific Contribution of the Thesis**

**Introduction**

The main objective of this study was to identify work-related risk factors for LBP serious enough to require treatment at one of the study site's occupational health clinics. Based on the results presented in the previous Chapter, it appears evident that there are strong, independent contributions from biomechanical and psychosocial risk factors in determining who reports LBP at the study site. Specific components of work have now been identified that could eventually lead to the development of primary prevention programs to reduce the incidence of LBP in the workplace. The significance of these findings is presented below, with each risk factor category presented in turn.

**Biomechanical Risk Factors**

Using the inter-quartile range for the random controls as the benchmark for odds ratio calculations, the results of the study's final logistic regression model suggest that estimates of the peak shear force in the lumbar spine (OR=1.9, 95% CI 1.2-3.2), the peak hand force required on the job (OR=1.8, 1.2-2.9), and the estimate of total disc compression over the course of a typical shift (OR=1.9, 1.3-2.9) are the most important biomechanical risk factors in this work environment. Figure 7.1
illustrates what these forces mean biomechanically.

BIOMECHANICAL RISK FACTORS

peak shear

cumulative disc compression

peak hand force

Figure 7.1: Biomechanical Risk Factors Identified

Peak Hand Force

Of all the workplace physical demands variables measured in previous studies, measures of heavy lifting, or other materials handling are probably the most common, and perhaps best established as a risk factor. The results of this study support the early pioneering work of people like Chaffin\textsuperscript{28}, and more recently, the epidemiologic studies by Punnett et al.\textsuperscript{6} and Nuwayhid et al.\textsuperscript{29}. The OR estimates in studies of manual materials handling are reported to range from 1.12 to 3.07\textsuperscript{30}. Our study falls within this range, with the multiple regression OR of 1.8. Our study may differ from others in that this variable was not restricted to just “lifting”, as pushes and pulls were also included under the “peak hand force” rubric. This is an important distinction, as large spinal forces are believed to be generated in response to such activities.\textsuperscript{23}
**Shear Force**

In reference to the lower back, shear force refers to the reactive forces that act perpendicular to the spinal column. These forces are developed by muscles reacting to the presence of loads acting on the lumbar spine, either from bent postures, especially with a load in the hands, or from push or pull actions.\(^3\)

While some biomechanical laboratory studies that have suggested high shear forces might be of importance in the pathogenesis of LBP\(^2\), there is little epidemiological evidence to support this. No well controlled epidemiological studies were found to have reported shear force as a risk factor for LBP. The only study found to have examined shear force was a cross-sectional survey of prevalent back pain in nurses aides.\(^3\) This study was a biomechanically-oriented investigation of cumulative loading in nurses aides. It did not measure subjects when they were working, nor did it control for any psychosocial factors. Instead, it used simulated postures for "stressful" tasks identified by the subjects which were transcribed onto a questionnaire by a trained interviewer for use in deriving biomechanical model estimates of disc compression and shear forces. These estimates from the "mocked" postures were then "multiplied up" by the amount of exposure time each task required per day, as reported by the subjects to derive the final cumulative force estimates.

Risk estimates were not generated by the study, since it was not epidemiologically-oriented. It did report, however, using simple t-tests, that cumulative shear and compressive forces, both for daily exposure and lifetime exposure, were higher in male nursing aides with back pain than in those without back pain. The relationship was not as strong or consistent for women. This gender disparity is interesting since only 8 male subjects without pain and 6 with pain were examined, compared to 52 female aides without pain and 95 with pain also participated in the
study. No comment was made as to why the association would be stronger in men, especially given the much smaller sample size, and therefore much lower study power for that group. (The cumulative shear variable was not available for this thesis thus no direct comparison can be made between the nurses aide study and the study presented in this thesis.)

Despite the evidence presented above, the clinical relevance of shear forces in spinal biomechanics are still not well understood. It is believed that shear forces in the lumbar spine are resisted primarily by the facet joints of the vertebrae, which are known to have abundant pain receptors. It is possible that high shear forces could lead to inflammation of the tissues in the facet joint region, including the annular fibres of the discs, which in turn could lead to the onset of pain.

Disc Compression
In relation to the lower back, disc compression refers to the force that pushes the vertebrae together, in response to forces developed by surrounding tissues during spinal loading, such as up and down lifting. Disc compression is a much more studied biomechanical force than is shear force, with many more biomechanical studies having presented it as a possible factor in the pathogenesis of LBP.

However, as with shear force, the epidemiological evidence in support of its role in the etiology of LBP is very limited. Only one study is known to the author to have estimated disc compression in individual study subjects, from data obtained while these subjects were at work. This was the case-control study by Punnett et al., in automobile assembly workers in Michigan. However, because of the way in which this study estimated disc compression (only for workers lifting 44N or greater), very few of the subjects had a compression estimate derived. The authors found no effect for disc compression on LBP risk in that study, which did however find a
strong effect for non-neutral trunk postures.

This is somewhat the reverse of the findings presented in this thesis, which reported a strong effect for (cumulative) disc compression, while the non-neutral trunk postures variable which had been deliberately scaled to try and replicate the Punnet study variable, was not associated with reported LBP once the other exposures were taken into account. The awkward posture index, as the non-neutral posture variable was labelled in this study, did show a modest bivariable regression association, OR =1.4 (95% CI 1.08-1.89). The loss of the modest effect in the multiple logistic regression analysis significance can perhaps be explained by the inclusion of direct estimates of the forces in the final study model. These forces may be the biomechanical consequences of the non-neutral postures reported by the Michigan study, and thus there was no explanatory power left for the "surrogate" variable once the actual forces were entered into the model.

The prospective cohort Boeing study also measured disc compression, but it used group-level exposures rather than individual workers. As discussed previously, this study did not find an association between any physical demands of work and the risk of filing a compensation claim for LBP.36

The Size of the Reported Effects
One other point about this other case-control study of LBP in autoworkers concerns comparing the size of odds ratios from different studies. The Punnett et al. study chose to report the OR for the continuously scaled posture index as a 0-100% comparison (i.e. comparing workers always in awkward postures with those never in those postures).6 This thesis chose to use the interquartile range of the random controls for determining the magnitude of the OR of continuously scaled variables. This rationale for using the interquartile range as a way of assigning a
"standardized" magnitude to the study OR's across risk factors is somewhat arbitrary.\textsuperscript{37} It was a compromise choice based on standard epidemiologic practice and the desire to be able to convey a meaningful statistic back to the study stakeholders.

It should be understood that if the range of interest for the OR estimates is expanded, for example to the 90th and 10th percentiles, instead of the 75th and 25th percentiles, the OR estimates become more extreme. For example, the OR for peak shear would increase from its reported value of 1.9, to 3.1 (95\% CI 1.03, 9.57). If the 95th and 5th percentiles are used, the estimate increase further to 4.0 (95\% CI 1.04, 16.03). The OR estimate of 8.09 (95\% CI 1.5-44.0) reported for non-neutral trunk postures in the Punnet et al. study was therefore understandably large, but it may not have been as reflective of plant floor exposures as the interquartile range comparison used here.

**Combined Biomechanical Effects**

Furthermore, because the statistical model underlying logistic regression implies that these risk estimates are multiplicative, and the results for each term are independent of one another, it is worth examining what the OR estimate would be for someone above the 75th percentile on all three biomechanical terms. The study's final model suggests that such workers would be at considerably elevated risks, as the product of the three OR estimates is 6.2, meaning that the risk for someone with high overall biomechanical demands increases about six-fold compared to subjects at the 25th percentile of the exposure range for all these factors. If the subject's questionnaire responses also indicate that they perceive the physical loading on their job to be high, then the overall risk of "physically demanding work" increases to almost 20 times that compared to subjects at the lower quartiles for all these factors. This is a clear indication of the strength of the association found in this
study between workplace physical demand and the etiology of reported LBP. However, these multiplicative estimates assume no significant interaction between the three variables, which could increase or decrease the combined effect presented above, depending on the nature of the interaction. Formal examination of interaction was not done due to the limited sample size. Use of additive statistical models rather than multiplicative ones is one possible way to examine this issue.37

Psychosocial Risk Factors
The most important psychosocial factors identified by the regression modelling are perceptions of the work being physically demanding (OR=3.2 95% CI 1.91-5.70), negative perceptions of the workplace social environment (OR=2.8, 1.4, 5.8), a perception of being under-employed relative to the education levels of other workers in similar jobs (OR=2.3, 1.1, 5.2), and a feeling of low control over how the work is being done (OR=1.9, 0.9, 4.1). Positive perceptions of coworker social support and high job satisfaction were both associated with an increased risk of reporting LBP to the worksite (OR=1.6, 1.1, 2.3; OR 1.6, 1.1, 2.4 respectively), which is contrary to what previous studies have suggested.11.19.

Self-Reported Physical Demands
This variable was included under the psychosocial rubric in this study because of the extensive amount of directly measured biomechanical information collected on the physical demands of work. The fact that it remains in a multiple logistic regression model together with these terms for the direct measures is perhaps an indication that there may indeed be more than one component to these self-reported demands, as discussed above under the strengths of the study, as well as in Appendix 6.3, on the Analysis of the Job Content Instrument. Differences in pain tolerance, or other tissue responses may be accounting for the independent effects observed in this study, or they may also be the result of limited overlap between the
measured and self-reported physical demand variables. Given the extensive nature of the clinical and biomechanical data collected for the overall IWH Integrated Study, it may be possible to further "deconstruct" the relationship between self-reported demands and LBP.

Workplace Social Environment
This scale differed from the coworker and supervisor support scales of the JCI in that it did not ask specifically about the individuals relationships with other people at work. Rather, its focus was more on the overall condition of the workplace with respect to whether it was a pleasant work environment, free from conflicts or harassment, with someone available for helping out with job problems. Workers with negative responses to these questions were at significantly increased risk of reporting LBP in the study setting. One other study has also recently reported an association between low workplace social support and musculoskeletal problems, including LBP, although the risk estimate (prevalence ratio) was considerably lower, at 1.6 (1.2-2.2) based on a support scale that had been categorized into tertiles. Two others did not find an association between workplace support and LBP.

The causal mechanism, if present, for this association is not understood. It is possible that it is an artefact of the study design - asking workers who had recently experienced a serious episode of LBP to describe their workplace may have caused recall bias to affect the results. Such workers could report a negative perception of the workplace because of their pain. However, the opposite effect was seen for both coworker support and job dissatisfaction, indicating that recall bias is not likely the reason for the finding. Based on the very low agreement observed (ICC=0.08) for this variable between the 65 pairs of cases and the job-matched controls examined, it appears as though this may be a variable that is more strongly influenced by individual workers than by the workplace. How this translates into increased risk
of reporting LBP is unclear, although as future research, it may be possible to examine correlates with this scale from the other data collected for the Integrated Study.

Job Satisfaction and Coworker Support
The findings for job satisfaction and coworker support are both opposite to the expected direction, as mentioned previously. This is in direct contradiction to the Boeing study that reported job dissatisfaction as the only work-related predictor of reporting LBP among commercial aircraft assembly workers. Our study used the very same question to assess dissatisfaction with the tasks of the job as was used in the Boeing study. It also used a second question, from the Whitehall study of British civil servants. This Whitehall question was more general in nature (i.e. “taking all things into consideration”), while the Boeing question was more task oriented. For both questions, the proportion of people dissatisfied with work was low (17% and 15% respectively). This low prevalence of work dissatisfaction was similar to that observed in the Boeing study, which may account for the low overall proportion of variance explained by the few risk factors identified in that study.

The modest increase in risk for better job satisfaction, and better coworker support may be an indication of the type of cases used in this study, which included workers with and without work absence due to LBP. It is possible that in order to stay at work with LBP, workers need the active support of their coworkers. The fact that they enjoy the work may explain why they are staying with it, despite the pain. As with the other psychosocial risk factors identified, future analyses of the full IWH data set may be able to test some of these hypothesized relationships.

Other Psychosocial Results
This is the first study known to the authors to report an association between a
feeling of being "over-educated" relative to other workers doing similar jobs. Since serious job dissatisfaction does not appear to be a prevalent problem at the study site it is not likely an indication of a generalized disgruntlement with work. Almost one third of cases (32%) reported their education level to be higher or much higher than other people in jobs like theirs, compared to 22% for the random controls, thus it is a common perception among the workers at the study site. This is an interesting finding that will require further study to explore the possible reasons for the association.

**The Relative Effect of Biomechanical and Psychosocial Risk Factors**

To determine the relative explanatory power of risk factors from these two domains, the regression parameters for logistic regression models restricted to either the biomechanical or psychosocial terms from the final model were compared. The criteria used were the -2 log likelihood (-2LL) chi square for covariates only and the adjusted $r^2$ statistic (after excluding self-rated physical demands from both models). The results of these comparisons indicate that the terms representing the directly measured biomechanical variables in the final model may be accounting for slightly more of the variance, with $r^2$ statistics of 0.17 and 0.12 for the biomechanical-only and psychosocial-only models respectively, excluding self-reported physical demands from either model because of its potential overlap between the two domains.

If these comparisons are re-run including the term for self-reported physical demands, the same picture of the relative effect of the two types of factors emerges, although the values of regression statistics change considerably. The adjusted $r^2$ statistics increase substantially when the perceptions of physical demands are also included, as do the -2LL values. The changes in the regression statistics, particularly
the difference in the -2LL between the combined model with and without the self-reported physical demands term clearly indicates the large contribution that this variable is making to the final model, and therefore to the reporting of LBP at the study setting.

Thus, in conclusion, it appears as though both biomechanical and psychosocial risk factors are strongly associated with the onset of reported LBP. However, based on the results presented immediately above, it may be better to refer to three types of risk factors - biomechanical, psychosocial, and perceived physical demands - since all three are clearly having important etiologic effects on the reporting of LBP at the study site.
Bibliography - DISCUSSION


13. Theorell T. Possible mechanisms beyond the relationship between the demand-control-support model and disorders of the locomotor system. In: Moon SD, Sauter SL, editors. Beyond biomechanics - Psychosocial aspects of musculoskeletal disorders in office work. Bristol: Taylor & Francis, 1995:


CONCLUSIONS

Overview
To briefly summarize the study’s main findings, the most important risk factors identified are in two categories: biomechanical factors, including peak shear force, peak hand force and cumulative disc compression; and psychosocial factors including perceptions of the physical demands of work, the workplace social environment, and a feeling of being “over-educated” relative to other workers in similar jobs. All six of these factors demonstrated substantial independent contributions to increasing the risk of reporting LBP in the study setting.

In addition to the core findings outlined above, workers reporting good job satisfaction and good co-worker support were also more likely to report LBP. This finding was contrary to what the literature might have predicted. Finally, the results also suggest that low control over their job may also be associated with the risk of reporting LBP, although this finding was of borderline statistical significance.

These risk factors were all identified by a backwards, stepwise logistic regression modelling process that fixed in terms for prior compensation claims for LBP, age, body mass index, marital status, preschool children, and smoking status, as these were considered possible confounders, based on prior studies and clinical judgement. Among these six factors, only the variable for prior WCB claims for LBP was found to be associated with an increased risk of LBP on its own. However, statistical adjustment for all six of these factors was carried out so that the risk estimates obtained from the final model might better reflect the relative importance of the workplace factors being examined, an important consideration if the results are to be used for future workplace interventions.

Based on a synthesis of the main results of this thesis with the existing literature on
etiologic studies of occupational LBP, a number of specific conclusion have been made. These are outlined below in Table 8.1.

1. Using direct measurements during actual job conditions, this study provides evidence of a clear and consistent association between the physical demands of work and the reporting of LBP at the workplace.

2. Using data obtained from an interview-assisted questionnaire, the study also provides important evidence of an association between specific work-related psychosocial factors and LBP reported at work.

3. To the author's knowledge, peak shear force has been identified as a risk factor for occupational LBP for the first time in an epidemiologic study.

4. Cumulative and peak physical loading at work both seem to make important, independent contributions to the risk of reporting LBP.

5. Exact job matching does a good job of controlling for the physical demands of work, but use of job categories or job titles likely leads to excessive misclassification error, and should not be used in studies purporting to assess or control for the physical demands of work. Job matching does not do a good job of controlling for psychosocial factors.

6. The "psychological demands" scale of the Job Content Instrument may need further revision for use in studies of musculoskeletal disorders. In its current form it may be inappropriate for such studies, especially in settings with high levels of physically demanding work.

7. In addition to direct assessments of the physical demands of work, workers' perceptions of the physical demands of work were also associated with reporting LBP. These self-reported demands correlate only modestly with measured demands, possibly indicating a high error component in the measured terms or a secondary worker-specific component to the self-reports, such as differences in tissue tolerance.

8. Job dissatisfaction does not appear to increase the risk of reporting LBP in the study setting, nor does low social support as measured by scales from the Job Content Instrument. These factors may be more important for extending LBP disability than for initiating the reporting of LBP.

Table 8.1: The Main Conclusions of the Thesis.
Recommendations for Future Work

As previously mentioned in the Preface, this thesis was part of a larger research framework that combined a number of objectives relating to the etiology and prognosis of occupational LBP. Given the study's very substantial costs, and the logistical complexities associated with running it, it is very unlikely that this study will ever be replicated in its current form. This is perhaps particularly true for the comprehensive hierarchy of biomechanical measures used for the "common metric" approach to assessing job-related physical demands. Consequently, the onus should be on extracting the maximum value out of the data that have already been collected, through additional analyses to further refine the study instruments, either psychosocial or biomechanical. The opportunity to have so much data, from both types of risk factors, from the same workers may never again be repeated.

While the study's exposure assessments proved themselves to be particularly expensive and thus a limiting factor on the overall design of the study, they may also prove to be one of its main legacies. The exposure data collected will be useful for a number of future analyses that could eventually lead to more cost efficient exposure assessments for future prospective cohort studies, or possibly lead to the development of "shop-floor" versions of the instruments that could be used in industry for monitoring their continuously changing work environments. For the biomechanical data, specific analyses proposed include the examination of possible threshold effects for risk for the main results reported in this thesis, as well as possible benchmarks for quality improvement programs. For the psychosocial data, further examination of the interesting findings regarding job satisfaction and education levels are planned. For example, do these results vary by workers' compensation claim status?

Although more etiologic research is still warranted, particularly with regards to
clarifying the role of peak shear in initiating LBP, and further work is needed to better understand the interaction between psychosocial and biomechanical risk factors in the workplace, the results of this study should also provide some of the required incentive for studies with more immediate practical value. Rather than waiting for confirmation of the findings from other studies, which may never happen given the aforementioned logistical and economic challenges that performing such research poses, the results of this study should be used to promote research into the ways and means of developing effective workplace interventions to reduce the incidence of occupational LBP. The findings of this study, in combination with other etiologic research, should help provide a strong rationale for adopting this "upstream" approach to coping with the burden of illness associated with work-related LBP.

Using the results of this study to develop and demonstrate an effective primary prevention program to reduce the incidence of LBP in the workplace could help dispel concerns in industry that researchers may be "finders" of problems but not "fixers". Pending a successful review of the study's findings in the academic community, developing such a program should now be feasible given the results of this study. The next step will be to build upon the relationship already developed with the study stakeholders during the etiologic study, by working closely with them to develop solutions to the problem of LBP in the workplace.
METHODOLOGIC APPENDICES
APPENDIX 4.1

Summary of New (International) Low-Back Pain Studies
## Appendix 4.1 Summary Table of Key Features of New International LBP Studies

<table>
<thead>
<tr>
<th>Study Group</th>
<th>Study Population</th>
<th>Design(s)</th>
<th>Musculo-Skeletal Condition(s)</th>
<th>Sample Size(s)</th>
<th>Exposures</th>
<th>Case Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MUSIC</strong> (Sweden)</td>
<td>Population Based (Town of Norrtälje)</td>
<td>Case/Control (Etiology)</td>
<td>Low Back Sprain/Strain</td>
<td>Cases Low 700 M Back 700 F</td>
<td>- Psychosocial Background - General Conditions - Working Tasks - Psychosocial - Work - Sleep Disturbance - Life Events - Physical - Clinical - Therapy</td>
<td>Via health care services in community (and questionnaire?)</td>
</tr>
<tr>
<td></td>
<td>20,000 Men &amp; Women Aged 25 - 59</td>
<td>Inception Cohort (Prognosis)</td>
<td>Neck/Shoulder Disorders</td>
<td>Neck 700 F Shoulder 400 M</td>
<td>Controls 700 M 700 F (Matched on age, sex and region to low back cases)</td>
<td></td>
</tr>
<tr>
<td><strong>IIW</strong> (Canada)</td>
<td>Worksite - large industrial employers - mostly male approx. 15,000 (largely female worksite in second site)</td>
<td>Case/Control (Etiology)</td>
<td>Low back sprain/strain</td>
<td>Case 150 Unmatched controls 150 Job matched controls 150</td>
<td>- Demographic - Injury Related - Physical Factors - Psychological Factors - Psychosocial Factors - Workplace Organization - Ergonomic Demands - Workers' Compensation Board Factors</td>
<td>Via worksite reporting (Health Services and Personnel)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inception Cohort (Prognosis)</td>
<td></td>
<td>300 Cases off work for 3 weeks or more</td>
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</tr>
<tr>
<td>STUDY GROUP</td>
<td>STUDY POPULATION</td>
<td>DESIGN(S)</td>
<td>MUSCULO-SKELETAL CONDITION(S)</td>
<td>SAMPLE SIZE(S)</td>
<td>EXPOSURES</td>
<td>CASE IDENTIFICATION</td>
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<tr>
<td>MUSKELI (Finland)</td>
<td>Worksite Based (largo pulp and paper company approx. 9,000)</td>
<td>Multiple 1. Mixed Cohort</td>
<td>1. Cohort Low Back Sprain/Strain Neck/Shoulder Upper Extremity Lower Extremity 2. Case/Control severe syndromes e.g. lumbar &amp; cervical root compression syndromes and rotator cuff tendinitis</td>
<td>1. 9,000</td>
<td>- Physical Workload ( ? )</td>
<td>Via Questionnaire (Cohort) and Occupational Health Care Units (Case/Control)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Case/Control (Etiology)</td>
<td>2. ? controls matched on age and sex</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>3. Case/Control (Prognosis)</td>
<td>3. ( ? )</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>4. Primary Intervention (prevent disorders)</td>
<td>4. ( ? )</td>
<td></td>
<td>- Non-experimental Interventions - Planned Study Interventions</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>5. Secondary Intervention (prevent long term disability)</td>
<td>5. ( ? )</td>
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</table>

This table was prepared in collaboration with Dr. Shellah Hogg-Johnson from the Institute for Work & Health. It is based on discussion held at a meeting of LBP researchers in Stockholm, in the fall of 1993. Each of the studies in the table was represented at this meeting. The purpose of the meeting was to enhance collaboration between LBP researchers and to ensure that the studies were not duplicating one another because of the expense associated with completing them. In other words, the studies were to complement one another rather than replicate. While the importance of the latter is recognized, the state of knowledge in LBP etiology and prognosis at the time of the meeting dictated that new efforts, rather than duplicate efforts be given priority.
<table>
<thead>
<tr>
<th>STUDY GROUP</th>
<th>STUDY POPULATION</th>
<th>DESIGN(S)</th>
<th>MUSCULO-SKELETAL CONDITION(S)</th>
<th>SAMPLE SIZE(S)</th>
<th>EXPOSURES</th>
<th>CASE IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEIDEN (Netherlands)</td>
<td>Worksite based 60 sites with approx. 50 employees each</td>
<td>Cohort with Nested Case/Control (Etiology)</td>
<td>Low back sprain/strain Neck/shoulder disorders</td>
<td>Cohort 2,500 Expected 360 cases Expected 720 controls (2:1 ratio)</td>
<td>- Physical load - at work - outside work - Psychosocial load - at work - outside work - Individual factors</td>
<td>Occupational Health Care Services in Community and Follow-up Questionnaire</td>
</tr>
<tr>
<td>MALMÖ (Sweden)</td>
<td>Population Based (City of Malmö) 53,000 men and women aged 45 - 64</td>
<td>Mixed Cohort (Etiology/Outcome)</td>
<td>Neck/Shoulder disorders</td>
<td>15,000 out of which cases of various duration will be identified</td>
<td>- Mechanical Factors - Psychosocial Factors - Lifestyle Factors - Anthropometry - Comorbidity</td>
<td>Via Questionnaire</td>
</tr>
<tr>
<td>REBUS (Sweden)</td>
<td>Population Based (Random sample from Stockholm Region) - men and women age 40 - 65 in 1993/4</td>
<td>Follow-up of earlier Cohort (23 years)</td>
<td>Musculoskeletal disorders Present MSK function</td>
<td>500</td>
<td>- Job History - Psychosocial Factors - Work - Leisure - Physical Workload - Work - Leisure</td>
<td>Via Questionnaire</td>
</tr>
</tbody>
</table>
APPENDIX 5.1

Job-Matched Control Recruitment Form
APPENDIX 5.1: REQUEST FORM FOR JOB-MATCHED CONTROLS

The following employee has been enrolled as a case in our back pain study.

Employee: ____________________________________________

Job: __________________________________________________

In order to better understand how the demands of the job can contribute to the onset of low back pain, we need to also study an uninjured person doing the same job as this case. Could you please provide us with the names of other employees doing the same job as the person listed above so that one or more of them can be contacted and asked to volunteer to be a job-matched control for the study? Thank you very much for your assistance.

Personnel doing the same job:

Shift 1 Supervisor: ____________________________ Telephone: ______________

Names:
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________

Shift 2 Supervisor: ____________________________ Telephone: ______________

Names:
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________

Shift 3 Supervisor: ____________________________ Telephone: ______________

Names:
________________________________________
________________________________________
________________________________________
________________________________________
________________________________________

Please leave this form for all shifts to complete and then mail or fax it to:
Jonathon Smith Phone: 4016 Mail: 086-003 Fax: 4022

(CASE ID#:__________)
APPENDIX 5.2

The IWH Integrated Study Baseline Questionnaire
QUESTIONNAIRE

ONTARIO UNIVERSITIES
BACK PAIN STUDY

Date of Interview ____/____/____
day mo yr
A. We would like to begin by asking you a few questions about yourself.

1. Your sex (circle number of your answer)
   1 MALE
   2 FEMALE

2. What is your date of birth? _____/_____/19____
   DAY MONTH YEAR

3. What is your marital status? (circle number)
   1 NOW MARRIED OR LIVING COMMON LAW.
   2 SINGLE (NEVER MARRIED).
   3 WIDOW OR WIDOWER.
   4 SEPARATED OR DIVORCED.

4. In what country were you born? (please specify)

5. If you were not born in Canada, in what year did you immigrate to Canada? 19____

6. To which ethnic or cultural group(s) do you or did your ancestors belong? (I'll circle as many numbers as you give me.)
   1 FRENCH
   2 ENGLISH
   3 GERMAN
   4 SCOTTISH
   5 IRISH
   6 ITALIAN
   7 UKRAINIAN
   8 DUTCH
   9 CHINESE
   10 JEWISH
   11 EAST INDIAN
   12 HUNGARIAN
   13 POLISH
   14 PORTUGUESE
   15 NORTH AMERICAN INDIAN
   16 METIS
   17 INUIT
   18 CANADIAN
   19 OTHER (please specify)

7.(a) Have you completed an apprenticeship program? (circle number)

   1 YES
   2 NO
(b) Other than an apprenticeship, what is the highest level of education that you have completed? (circle number)

1 NO FORMAL SCHOOLING  
2 SOME PRIMARY SCHOOL  
3 PRIMARY SCHOOL  
4 SOME SECONDARY OR HIGH SCHOOL  
5 COMPLETED SECONDARY OR HIGH SCHOOL  
6 SOME COMMUNITY COLLEGE, TECHNICAL COLLEGE, CEGEP, OR NURSING PROGRAM  
7 COMPLETED COMMUNITY COLLEGE, TECHNICAL COLLEGE, CEGEP, OR NURSING PROGRAM  
8 SOME UNIVERSITY (NOT COMPLETED)  
9 UNIVERSITY DEGREE (COMPLETED)

8. (a) Do you have children living with you (either your own or from another relationship)? (circle number)

1 YES  
2 NO ~ Go to Question 9.

(b) If YES, how many children? (please specify) _____

(c) If YES, what are their ages? (please specify) _____, _____, _____, _____

(d) If YES, who carries the bulk of responsibility for household tasks and childcare in your home? (circle number)

1 I DO.  
2 MY SPOUSE/PARTNER DOES.  
3 WE SHARE EQUALLY.  
4 NONE OF THE ABOVE.

9. Are you the main wage earner in your household? (circle number)

1 YES  
2 NO
B. Next we want to ask you some questions about the back pain which you reported at work. Throughout this section, by back pain we mean pain in the back or buttocks, by leg pain we mean pain in the lower limb (including foot) coming from the back (sciatica).

1. HAVE YOU HAD BACK PAIN OR LEG PAIN IN THE PAST WEEK? (circle number)
   - 1 YES
   - 2 NO → Go to Question 25.

1a. → If YES, for how long has this episode of back pain or leg pain (sciatica) lasted? (Check one box in each row)

<table>
<thead>
<tr>
<th>BACK PAIN/</th>
<th>LEG OR FOOT PAIN</th>
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<tbody>
<tr>
<td>INCLUDING BUTTOCKS</td>
<td>(SCIATICA)</td>
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<tr>
<th>&lt; 1 Week</th>
<th>1-6 Wks.</th>
<th>6 Wks.</th>
<th>3-6 Mos.</th>
<th>&gt;6 Mos.</th>
<th>None During This Episode</th>
</tr>
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2. Where was this pain? (circle one or more numbers)
   - 1 BACK AND/OR BUTTOCKS ONLY → Go to Question 7.
   - 2 TRAVELLED INTO ONE LEG
   - 3 TRAVELLED INTO BOTH LEGS

3. If the pain travelled into your legs, did it: (circle number)
   - 1 TRAVEL TO THE THIGH ONLY (ABOVE THE KNEE)?
   - 2 TRAVEL BELOW THE KNEE (TO THE CALF OR FOOT)?

4. Have you also sometimes had numbness in the legs or foot? (circle number)
   - 1 YES
   - 2 NO

5. If the pain travelled into your legs, did it sometimes get worse with coughing or sneezing? (circle number)
   - 1 YES
   - 2 NO

6. If the pain travelled into your legs, was the back pain worse or was the leg pain worse? (circle number)
   - 1 BACK PAIN IS WORSE
   - 2 LEG PAIN IS WORSE
   - 3 BOTH PAINS ARE ABOUT THE SAME OR IT VARIES FROM ONE TO THE OTHER

7. Which of the following problems has limited your activity the most? (circle number)
   - 1 BACK-RELATED PROBLEM OR LEG PAIN (SCIATICA)
   - 2 PAIN IN OTHER JOINTS, SUCH AS HIPS OR KNEES
   - 3 OTHER SYMPTOMS, SUCH AS BREATHING PROBLEMS OR HEART PROBLEMS
   - 4 NOTHING, HAD NO LIMITATIONS
8. Have you, in association with your back pain, lost the control of your bladder or bowels? (circle number)
   1 YES
   2 NO

9. When have you had pain in the back? (I will circle as many numbers as you give me.)
   1 AT WORK
   2 DURING RECREATIONAL ACTIVITIES
   3 AT REST
   4 AT NIGHT
   5 ALL THE TIME
   6 OTHER (please specify) __________________________

10a. In the past week, if you had pain when you slept, did it wake you up? (circle number)
   1 YES
   2 NO

10b. If YES, did the pain improve if you got up? (circle number)
   1 YES
   2 NO
   3 DON'T KNOW

11. In the past week, was your back usually stiff when you got up? (circle number)
   1 YES
   2 NO

   If YES, how long did the stiffness last? (please specify length of time) _______________

12. Have you tried complete bed rest for 3 days or more for your back/leg pain? (circle number)
   1 YES
   2 NO

   If YES, did you get any relief from your pain? (appropriate box)
   □ Not at all (a) □ Slight (b) □ Moderate (c) □ Significant (d)

13. Overall, is your back or leg pain (sciatica) problem better or worse than you expected it to be at this point? (appropriate box)
   □ Much (a) □ Somewhat (b) □ What I Expected □ Somewhat (c) □ Much (d)
   Better Better Expected Worse
14. If you were to spend the rest of your life with your back symptoms just the way they are now, how would you feel about that? (circle number)

1 DELIGHTED
2 PLEASED
3 MOSTLY SATISFIED
4 MIXED (ABOUT EQUALLY SATISFIED AND DISSATISFIED)
5 MOSTLY DISSATISFIED
6 UNHAPPY
7 TERRIBLE

C. When your back or leg hurts, you may find it difficult to do some of the things you normally do. This list contains some sentences that people have used to describe themselves when they have back pain or sciatica. As I read them, you may find that some stand out because they describe you today. Please think of yourself right now. When I read a sentence that describes you today please tell me and I will circle "1" for YES and "2" for NO.

1. I stay at home most of the time because of my back problem or leg pain (sciatica).
   1 YES
   2 NO

2. I change position frequently to try and get my back or leg comfortable.
   1 YES
   2 NO

3. I walk more slowly than usual because of my back problem or leg pain (sciatica).
   1 YES
   2 NO

4. Because of my back problem, I am not doing any of the jobs that I usually do around the house.
   1 YES
   2 NO

5. Because of my back problem, I use a handrail to get upstairs.
   1 YES
   2 NO

6. Because of my back problem, I lie down to rest most often.
   1 YES
   2 NO

7. Because of my back problem, I have to hold onto something to get out of an easy chair.
   1 YES
   2 NO

8. Because of my back, I try to get other people to do things for me.
   1 YES
   2 NO
9. I get dressed more slowly than usual because of my back problem or leg pain.
   1   YES
   2   NO

10. I only stand for short periods of time because of my back or leg pain.
    1   YES
    2   NO

11. Because of my back problem, I try not to bend or kneel down.
    1   YES
    2   NO

12. I find it difficult to turn over in bed because of my back problem or leg pain.
    1   YES
    2   NO

13. My back or leg is painful almost all the time.
    1   YES
    2   NO

14. I find it difficult to get out of a chair because of my back problem or leg pain (sciatica).
    1   YES
    2   NO

15. My appetite is not very good because of my back pain.
    1   YES
    2   NO

16. I have trouble putting on my socks (or stockings) because of my back problem or leg pain (sciatica).
    1   YES
    2   NO

17. I only walk short distances because of my back problem or leg pain (sciatica).
    1   YES
    2   NO

18. I sleep less well because of my back problem.
    1   YES
    2   NO

    1   YES
    2   NO
20. I sit down for most of the day because of my back.
   1  YES
   2  NO

21. I avoid heavy jobs around the house because of my back problem.
   1  YES
   2  NO

22. Because of my back problem I am irritable and bad tempered with people more than usual.
   1  YES
   2  NO

23. Because of my back problem, I go up stairs more slowly than usual.
   1  YES
   2  NO

24. I stay in bed most of the time because of my back problem or leg pain (sciatica).
   1  YES
   2  NO

25. What is your height? (please specify) ________ feet + inches or _________ cm

26. What is your weight? (please specify) ________ lbs. or _________ kg

D. Our next questions are about back problems before this current episode of back pain. Therefore, we would like to ask you about other back pain which you may have experienced and how that pain may have affected your day-to-day activities. Reminder: By back pain we mean pain in the back or buttocks, by leg pain we mean pain in the lower limb (including foot) coming from the back (sciatica).

1. Have you had back pain in the last year? (circle number)
   1  YES
   2  NO → Go to Question 9.

2. In the past year, how bad was your worst back pain, where 0 is No Pain and 10 is pain As bad as it could be?
   0 1 2 3 4 5 6 7 8 9 10
   No pain
   As bad as it could be

3. In the past year, on average, how intense was your back pain (that is, your usual pain at the times you were experiencing pain)?
   0 1 2 3 4 5 6 7 8 9 10
   No pain
   As bad as it could be

4. About how many days in the last year have you been kept from your work because of back pain?
   ________ DAYS
5. In the past year, how much has back pain interfered with your daily activities rated on a 0-10 scale, where 0 is no interference and 10 is unable to carry on any activities?

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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<tbody>
<tr>
<td>No Interference</td>
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<td>Unable to carry on any activities</td>
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</table>

6. In the past year, how much has back pain changed your ability to take part in recreational, social and family activities where 0 is no change and 10 is extreme change?

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Change</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme Change</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. In the past year, how much has back pain changed your ability to work (including housework) where 0 is no change and 10 is extreme change?

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Change</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme Change</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8a. In the past year, have you had an episode of back pain or leg pain that lasted at least one day? (circle number)

- 1 YES
- 2 NO → Go to Question 9.

8b. If YES, have any of these episodes lasted more than one week? (circle number)

- 1 YES
- 2 NO

8c. In the past year, have you had 5 or more episodes that lasted more than one day? (circle number)

- 1 YES
- 2 NO

9. In your lifetime, how many episodes of back pain or leg pain (sciatica) have you had that lasted at least one day, but eventually went away completely? (circle number)

- 1 NONE → Go to Question 11a.
- 2 1-5 EPISODES
- 3 MORE THAN 5 EPISODES

10. Were any of these episodes a Workers' Compensation claim? (circle number)

- 1 YES
- 2 NO
11a. Prior to this episode of back pain, did you ever consult a doctor or other health care provider for any episode of back or leg pain (sciatica)? (circle number)

- 1 YES
- 2 NO - Go to Section E, Page 10.

11b. If YES, how many months or years ago did you first consult a doctor or other health care provider? (write in number)

   ___ Months or ___ Years Ago

12. If yes, how would you rate the following overall for these previous episodes of back or leg pain? (Do not include current episode. Place a "✓" in one appropriate box on each line.)

   The concern health care providers showed for your problem?
   □ Excellent (1)  □ Very Good (3)  □ Good (3)  □ Fair (4)  □ Poor (5)

   The effectiveness of the treatment prescribed for you?
   □ Excellent (1)  □ Very Good (3)  □ Good (3)  □ Fair (4)  □ Poor (5)

   The care you received, overall, for your problem?
   □ Excellent (1)  □ Very Good (3)  □ Good (3)  □ Fair (4)  □ Poor (5)
E. Now we would like to ask you a few questions about how you sleep. Please answer each question by choosing the one answer that best fits.

1. Do you have forceful snoring and/or interruptions to your breathing during sleep?  
   - Never  - Rarely  - Sometimes  - Often  - Don't Know

2. Have you been told you are a restless sleeper, e.g., move your legs or kick?  
   - Never  - Rarely  - Sometimes  - Often  - Don't Know

3. Do you suffer from nightmares or wake up frightened and crying out?  
   - Never  - Rarely  - Sometimes  - Often  - Don't Know

4. Do you sleep or fall asleep when you are sitting, e.g., reading, watching TV?  
   - Never  - Rarely  - Sometimes  - Often  - Don't Know

5. Do you feel sleepy or fall asleep when you are doing something, e.g., driving, talking to people?  
   - Never  - Rarely  - Sometimes  - Often  - Don't Know

The next questions ask you to describe your experience of sleep in the last week.

6. Have you had any problem sleeping?  
   - Never  - Rarely  - Sometimes  - Often  - Don't Know

7. Have you had any difficulty falling asleep?  
   - Never  - Rarely  - Sometimes  - Often  - Don't Know

8. Have you awakened before you want to?  
   - Never  - Rarely  - Sometimes  - Often  - Don't Know

9. Have you slept for less than five hours?  
   - Never  - Rarely  - Sometimes  - Often  - Don't Know

10. Have you repeatedly awakened during your sleep time?  
    - Never  - Rarely  - Sometimes  - Often  - Don't Know

11. Have you awakened from sleep not feeling refreshed or thoroughly rested?  
    - Never  - Rarely  - Sometimes  - Often  - Don't Know

12. Have you awakened with aches or pains or stiffness?  
    - Never  - Rarely  - Sometimes  - Often  - Don't Know

13. Do you work shifts? (circle number)  
    1 YES  
    2 NO

14. During regular working hours at what time do you normally go to bed? (please write in time and specify if a.m. or p.m.)

15. During regular working hours at what time do you normally get up? (please write in time and specify if a.m. or p.m.)
F. 1. Other health conditions are sometimes related to back pain. In the past year, have you had any other health conditions which appear on the following list? Please tell me and I will check the appropriate box. If you have seen a doctor or received medication for this condition, please tell me that as well.

<table>
<thead>
<tr>
<th>HEALTH CONDITION</th>
<th>DO YOU HAVE THIS CONDITION?</th>
<th>BEEN TREATED IN THE LAST YEAR? (i.e. saw doctor, taking pills)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asthma/bronchitis/emphysema</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>High blood pressure</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Heart trouble/pacemaker</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effects of stroke</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Troubles with balance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epilepsy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depression/anxiety</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vision loss even with glasses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hearing loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chronic foot trouble</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kidney troubles/urine infection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stomach ulcers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cancer (other than skin)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psoriasis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin infection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intestinal disorders</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The following questions ask about other recent aspects of your health.

2. Have you had persistent fevers in the past two weeks (over 37.7 degrees Celsius or 99.9 degrees Fahrenheit)? (circle number)

   1 YES
   2 NO
   3 DON'T KNOW
3a. In the last two months have you lost any weight? (circle number)
   - 1 YES
   - 2 NO — Go to Question 4.
   - 3 DON'T KNOW

3b. - If YES, how much weight have you lost? (write in answer)
   ___ lbs. or ___ kg.

3c. Were you trying to lose weight? (circle number)
   - 1 YES
   - 2 NO

4. Do you smoke cigarettes? (circle number)
   - 1 YES
   - 2 NO

5. In the past 12 months, have you taken an alcoholic drink? (Please check one box)
   Twice a day or more (1)
   Daily or almost daily (2)
   Once or twice a week (3)
   Once or twice a month (4)
   Special Occasions only (5)
   No (6)

6a. Have you ever taken cortisone or prednisone regularly in the past? (circle number)
   - 1 YES
   - 2 NO

6b. - If YES, are you still taking it regularly? (circle number)
   - 1 YES
   - 2 NO

The following questions ask about hospitalizations.

7. Have you ever been hospitalized for back surgery? (circle number)
   - 1 YES
   - 2 NO
   - If YES, when did it occur? (please specify) ________________________________
8. Other than back surgery, have you ever been hospitalized because of your back? *(circle number)*

   - 1 YES
   - 2 NO

   - If YES, please state why, where, and when it occurred.

### HOSPITALIZATIONS FOR BACK

<table>
<thead>
<tr>
<th>REASON</th>
<th>LOCATION</th>
<th>YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. In the past 5 years, have you had any other major surgery or hospitalization?

   - 1 YES
   - 2 NO

   - If YES, please state what it was for and when it occurred. *(We've put one in as an example.)*

### OTHER SURGERIES/HOSPITALIZATIONS

<table>
<thead>
<tr>
<th>REASON</th>
<th>YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>example: appendectomy</em></td>
<td>1989</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The following questions ask about injuries or work-related conditions not mentioned above.

10. Have you had any other injuries or conditions which have left you with persistent problems and/or required lost time from work? (circle number)

-   1  YES
    2  NO

- If YES, please fill in the following chart.

<table>
<thead>
<tr>
<th>PART OF BODY INJURED</th>
<th>TYPE OF INJURY/CONDITION</th>
<th>DESCRIBE YOUR PERSISTENT PROBLEM</th>
<th>YEAR</th>
<th>WCB CLAIM? YES/NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>example: arm</td>
<td>tendinitis</td>
<td>pain</td>
<td>1990</td>
<td>yes</td>
</tr>
</tbody>
</table>


11a. On most days do you have pain, aching, or stiffness in the joints of your hands or wrists? (circle number)

-   1  YES
    2  NO

11b. - If YES, is the pain, aching, or stiffness mild, moderate or severe? (place "✓" on appropriate lines)

LEFT HAND:  
- NONE  
- MILD  
- MODERATE  
- SEVERE

RIGHT HAND:  
- NONE  
- MILD  
- MODERATE  
- SEVERE

12a. On most days do you have pain, aching, or stiffness in either of your knees? (circle number)

-   1  YES
    2  NO

12b. - If YES, is the pain, aching or stiffness mild, moderate or severe? (place "✓" on appropriate lines)

LEFT KNEE:  
- NONE  
- MILD  
- MODERATE  
- SEVERE

RIGHT KNEE:  
- NONE  
- MILD  
- MODERATE  
- SEVERE

13. On most days, do you have pain, aching, or stiffness in any of your joints? (Do not include back. Circle number.)

1  YES
2  NO
14a. Has your doctor ever told you that you have arthritis? (circle number)

1 YES
2 NO → Go to Question 15.

14b. What type of arthritis were you told you had? (circle numbers which apply)

1 OSTEARTHRITIS (ALSO CALLED DEGENERATIVE ARTHRITIS)
2 RHEUMATOID ARTHRITIS
3 GOUT
4 OTHER (please specify) ______________________________

15. During the past 4 weeks, did the condition of any of the following joints limit your usual activities? (circle one number for each line)

<table>
<thead>
<tr>
<th>Joint</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHOULDER</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>ELBOWS</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>HANDS</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>NECK</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>HIPS</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>KNEES</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>ANKLE OR FOOT</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

G. These next questions ask for your views about your health. Answer every question by telling me the appropriate number. If you are unsure about how to answer a question, please give the best answer you can. I can write a comment in the left margin if you wish.

1. In general, would you say your health is: (circle one number)

   1 EXCELLENT
   2 VERY GOOD
   3 GOOD
   4 FAIR
   5 POOR

2. Compared to one year ago, how would you rate your health in general now? (circle one number)

   1 MUCH BETTER NOW THAN ONE YEAR AGO
   2 SOMEWHAT BETTER NOW THAN ONE YEAR AGO
   3 ABOUT THE SAME
   4 SOMEWHAT WORSE NOW THAN ONE YEAR AGO
   5 MUCH WORSE NOW THAN ONE YEAR AGO
HEALTH AND DAILY ACTIVITIES

3. The following questions are about activities you might do during a typical day. Does your health limit you in these activities? If so, how much? (circle 1, 2, or 3 on each line)

<table>
<thead>
<tr>
<th>Activity Description</th>
<th>Yes Limited a Lot</th>
<th>Yes, Limited a Little</th>
<th>No, Not Limited at All</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Vigorous activities such as running, lifting heavy objects, participating in strenuous sports.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>b. Moderate activities such as moving a table, pushing a vacuum cleaner, bowling, or playing golf</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>c. Lifting or carrying groceries</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>d. Climbing several flights of stairs</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>e. Climbing one flight of stairs</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>f. Bending, kneeling, or stooping</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>g. Walking more than a mile</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>h. Walking several blocks</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>i. Walking one block</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>j. Bathing or dressing yourself</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

4. During the past week, have you had any of the following problems with your work or other regular daily activities as a result of your physical health? (Please answer YES or NO for each question by circling 1 or 2 on each line)

<table>
<thead>
<tr>
<th>Problem Description</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Cut down on the amount of time you spent on work or other activities</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>b. Accomplished less than you would like</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>c. Didn't do work or other activities as carefully as usual</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

5. During the past week, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)? (Please answer YES or NO for each question by circling 1 or 2 on each line)

<table>
<thead>
<tr>
<th>Problem Description</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Cut down on the amount of time you spent on work or other activities</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>b. Accomplished less than you would like</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>c. Didn't do work or other activities as carefully as usual</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
6. During the past week, to what extent have your physical health or emotional problems interfered with your normal social activities with family, friends, neighbours, or groups? (circle one number)

1. NOT AT ALL
2. SLIGHTLY
3. MODERATELY
4. QUITE A BIT
5. EXTREMELY

7. How much bodily pain have you had during the past week? (circle one number)

1. NONE
2. VERY MILD
3. MILD
4. MODERATE
5. SEvere
6. VERY SEVERE

8. During the past week, how much did pain interfere with your normal work (including work both outside the home and housework)? (circle one number)

1. NOT AT ALL
2. A LITTLE BIT
3. MODERATELY
4. QUITE A BIT
5. EXTREMELY
YOUR FEELINGS

9. These questions are about how you feel and how things have been with you during the past week. For each question, please indicate the one answer that comes closest to the way you have been feeling.

How much of the time during the last week .... *(circle one number on each line)*

<table>
<thead>
<tr>
<th>Question</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. did you feel full of pep?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>b. have you been a very nervous person?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>c. have you felt so down in the dumps nothing could cheer you up?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>d. have you felt calm and peaceful?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>e. did you have a lot of energy?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>f. have you felt downhearted and blue?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>g. did you feel worn out?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>h. have you been a happy person?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>i. did you feel tired?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>j. has your health limited your social activities <em>(like visiting with friends or close relatives)</em>?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>
10. Please choose the answer that best describes how true or false each of the following statements is for you. (*circle one number on each line*)

<table>
<thead>
<tr>
<th></th>
<th>Definitely True</th>
<th>Mostly True</th>
<th>Not Sure</th>
<th>Mostly False</th>
<th>Definitely False</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. I seem to get sick a little easier than other people.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>b. I am as healthy as anybody I know.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>c. I expect my health to get worse.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>d. My health is excellent.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

H. YOUR WORK

Please tell me the one answer that best fits your job situation. Sometimes none of the answers fits exactly.

1. My job requires that I learn new things.
   - Often (1)
   - Sometimes (2)
   - Rarely (3)
   - Never/Almost never (4)

2. My job involves a lot of repetitive work.
   - Often (1)
   - Sometimes (2)
   - Rarely (3)
   - Never/Almost never (4)

3. My job requires me to be creative.
   - Often (1)
   - Sometimes (2)
   - Rarely (3)
   - Never/Almost never (4)

4. My job allows me to make a lot of decisions on my own.
   - Often (1)
   - Sometimes (2)
   - Rarely (3)
   - Never/Almost never (4)

5. My job requires a high level of skill.
   - Often (1)
   - Sometimes (2)
   - Rarely (3)
   - Never/Almost never (4)
6. On my job, I have freedom to decide how I do my work.
   - Often (1)
   - Sometimes (2)
   - Rarely (3)
   - Never/Almost never (4)

7. I get to do a variety of different things on my job.
   - Often (1)
   - Sometimes (2)
   - Rarely (3)
   - Never/Almost never (4)

8. I have a lot of say about what happens on my job.
   - Often (1)
   - Sometimes (2)
   - Rarely (3)
   - Never/Almost never (4)

9. I have an opportunity to develop my own special abilities.
   - Often (1)
   - Sometimes (2)
   - Rarely (3)
   - Never/Almost never (4)

10. I have control over how my work area is set up. (e.g. I can change the height of my chair, alter positioning of equipment, vary my bench heights, etc.)
    - Strongly agree
    - Agree (2)
    - Disagree (3)
    - Strongly disagree (4)

11. My job requires working very fast.
    - Often (1)
    - Sometimes (2)
    - Rarely (3)
    - Never/Almost never (4)

12. My job requires working very hard.
    - Often (1)
    - Sometimes (2)
    - Rarely (3)
    - Never/Almost never (4)

13. My job requires lots of physical effort.
    - Often (1)
    - Sometimes (2)
    - Rarely (3)
    - Never/Almost never (4)

14. I am asked to do an excessive amount of work.
    - Often (1)
    - Sometimes (2)
    - Rarely (3)
    - Never/Almost never (4)

15. I have enough time to get the job done.
    - Often (1)
    - Sometimes (2)
    - Rarely (3)
    - Never/Almost never (4)

16. My work requires rapid and continuous physical activity.
    - Often (1)
    - Sometimes (2)
    - Rarely (3)
    - Never/Almost never (4)
17. I am free from conflicting demands that others make.
   □ Often (1) □ Sometimes (2) □ Rarely (3) □ Never/Almost never (4)

18. My job security is good.
   □ Strongly agree (1) □ Agree (2) □ Disagree (3) □ Strongly disagree (4)

19. My supervisor cares about those under him/her.
   □ Often (1) □ Sometimes (2) □ Rarely (3) □ Never/Almost never (4)

20. My supervisor pays attention to what I am saying.
   □ Often (1) □ Sometimes (2) □ Rarely (3) □ Never/Almost never (4)

21. My supervisor is helpful in getting the job done.
   □ Often (1) □ Sometimes (2) □ Rarely (3) □ Never/Almost never (4)

22. My supervisor is successful in getting people to work together.
   □ Often (1) □ Sometimes (2) □ Rarely (3) □ Never/Almost never (4)

23. I get along well with my supervisor.
   □ Strongly agree (1) □ Agree (2) □ Disagree (3) □ Strongly disagree (4)

24. There is a pleasant atmosphere at my workplace.
   □ Strongly agree (1) □ Agree (2) □ Disagree (3) □ Strongly disagree (4)

25. My fellow workers are understanding when I have a bad day.
   □ Strongly agree (1) □ Agree (2) □ Disagree (3) □ Strongly disagree (4)

26. My fellow workers are supportive.
   □ Strongly agree (1) □ Agree (2) □ Disagree (3) □ Strongly disagree (4)

27. There are frequent conflicts with my supervisor.
   □ Strongly agree (1) □ Agree (2) □ Disagree (3) □ Strongly disagree (4)
28. I feel I am harassed at work because of my race or sex.

☐ Strongly agree (1)  ☐ Agree (2)  ☐ Disagree (3)  ☐ Strongly disagree (4)

29. There are frequent conflicts at my work site.

☐ Strongly agree (1)  ☐ Agree (2)  ☐ Disagree (3)  ☐ Strongly disagree (4)

30. There is nobody at work I can talk to about job problems.

☐ Strongly agree (1)  ☐ Agree (2)  ☐ Disagree (3)  ☐ Strongly disagree (4)

31. My fellow workers take a personal interest in me.

☐ Often (1)  ☐ Sometimes (2)  ☐ Rarely (3)  ☐ Never/Almost never (4)

32. My fellow workers are helpful in getting the job done.

☐ Often (1)  ☐ Sometimes (2)  ☐ Rarely (3)  ☐ Never/Almost never (4)

33. I am appropriately respected and rewarded by my company for my work.

☐ Often (1)  ☐ Sometimes (2)  ☐ Rarely (3)  ☐ Never/Almost never (4)

34. My skills and abilities are "vital" to my work group or unit.

☐ Often (1)  ☐ Sometimes (2)  ☐ Rarely (3)  ☐ Never/Almost never (4)

35. I feel my immediate supervisor considers my job very important.

☐ Often (1)  ☐ Sometimes (2)  ☐ Rarely (3)  ☐ Never/Almost never (4)

36. My fellow workers consider my job very important.

☐ Often (1)  ☐ Sometimes (2)  ☐ Rarely (3)  ☐ Never/Almost never (4)

37. I enjoy the tasks involved in my job.

☐ Almost always (1)  ☐ Some of the time (2)  ☐ Never (3)

38. Compared to other people in jobs like mine, my level of education (school, college, etc.) is:

Much Higher (1)  Higher (2)  About the same (3)  Lower (4)  Much lower (5)
39. Compared with previous jobs, my current job requires less skill. (Do not count previous jobs you have held for less than 6 months.)

☐ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree ☐ No previous job

40. Compared with 1 year ago, the physical demands of my job (e.g. lifting, twisting, and so on) are:

- Much less
- A little less
- About the same
- A little more
- Much more
- Not employed 1 year ago

41. Compared with 1 year ago, the control I have over my work is:

- Much less
- A little less
- About the same
- A little more
- Much more
- Not employed 1 year ago

42. About your job in general - how satisfied are you with your job as a whole taking everything into consideration?

☐ Very satisfied ☐ Satisfied ☐ Dissatisfied ☐ Very dissatisfied

43. Working at my present job gives me less seniority than my previous job.

☐ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree ☐ No previous job

44. What is your current job title/trade?

Job title/Trade: ________________________________

Describe your job: ________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Cycle time (if applicable) : ________________________________

Starting date of current job: Month _______ Year _______

[Not starting date for G.M.]
45. How physically demanding on your body is your job? (circle number)

0
1 very, very light
2
3 very light
4
5 usually light
6
7 a bit demanding
8
9 demanding
10
11 very demanding
12
13 very, very demanding
14

I. Next we want to ask you a few more questions about your job.

1. Do you need permission or do you have to find someone to take your place if you leave your work area for five or ten minutes? (check box)
   - Never (1)
   - Sometimes (2)
   - Always (3)

2. How much do workers take part in decision making in the workplace?
   - Often (1)
   - Sometimes (2)
   - Rarely (3)
   - Never / Almost never (4)

3. I feel employees ideas/opinions are listened to by management.
   - Strongly agree (1)
   - Agree (2)
   - Disagree (3)
   - Strongly disagree (4)

4. I can influence the way work is organised in my work area.
   - Strongly agree (1)
   - Agree (2)
   - Disagree (3)
   - Strongly disagree (4)

5. Safety is considered equally with production and quality goals in management thinking and plant operations.
   - Often (1)
   - Sometimes (2)
   - Rarely (3)
   - Never / Almost never (4)

6. Management is committed to keeping workers employed when injuries or disabilities occur.
   - Often (1)
   - Sometimes (2)
   - Rarely (3)
   - Never / Almost never (4)
7. Management encourages employees to shut down an unsafe machine or stop the work process when an unsafe condition arises.
   □ Strongly agree (1) ☒ Agree (2) □ Disagree (3) □ Strongly disagree (4)

8. Management encourages employees to promptly report physical symptoms arising from job tasks.
   □ Strongly agree (1) □ Agree (2) □ Disagree (3) □ Strongly disagree (4)

9. Management encourages supervisors to provide "light duties" or reduced working hours for workers who are recovering from an injury.
   □ Strongly agree (1) □ Agree (2) □ Disagree (3) □ Strongly disagree (4)

J. In the last 2 years have you had any deeply troubling personal experiences or severe stress (e.g., loss of a loved one, serious marital, financial, or legal problems, robberies, etc.)?
   1. YES
   2. NO
   - If yes, please specify. __________________________________________________________

K. Next we would like to know about how you have been feeling in the past week. Please tell me the phrase or number below which comes closest and I will circle it. Don't take too long over your replies: your immediate reaction to each item will probably be more accurate than a long thought-out response.

1. I feel tense or "wound-up":
   1. Most of the time
   2. A lot of the time
   3. Time to time, occasionally
   4. Not at all

2. I still enjoy the things I used to enjoy:
   1. Definitely as much
   2. Not quite so much
   3. Only a little
   4. Hardly at all

3. I get a sort of frightened feeling as if something awful is about to happen:
   1. Very definitely and quite badly
   2. Yes, but not too badly
   3. A little, but it doesn't worry me
   4. Not at all
4. I can laugh and see the funny side of things:
   1. As much as I always could
   2. Not quite so much now
   3. Definitely not so much now
   4. Not at all

5. Worrying thoughts go through my mind:
   1. A great deal of the time
   2. A lot of the time
   3. From time to time but not too often
   4. Only occasionally

6. I feel cheerful:
   1. Not at all
   2. Not often
   3. Sometimes
   4. Most of the time

7. I can sit at ease and feel relaxed:
   1. Definitely
   2. Usually
   3. Not often
   4. Not at all

8. I feel as if I am slowed down:
   1. Nearly all the time
   2. Very often
   3. Sometimes
   4. Not at all

9. I get a sort of frightened feeling like 'butterflies' in the stomach:
   1. Not at all
   2. Occasionally
   3. Quite often
   4. Very often

10. I have lost interest in my appearance:
    1. Definitely
    2. I don't take so much care as I should
    3. I may not take quite as much care
    4. I take just as much care as ever
L. People's lives are very different. In this section we would like to ask you about how you see yourself and your situation. How strongly do you agree or disagree with each of the following statements as they describe your life?

1. I have little control over the things that happen to me. (check appropriate box)

   Strongly agree (3)  Agree (2)  Disagree (3)  Strongly disagree (4)
   [ ] [ ] [ ] [ ]

2. There is really no way I can solve some of the problems I have.

   Strongly agree (3)  Agree (2)  Disagree (3)  Strongly disagree (4)
   [ ] [ ] [ ] [ ]

3. There is little I can do to change many of the important things in my life.

   Strongly agree (3)  Agree (2)  Disagree (3)  Strongly disagree (4)
   [ ] [ ] [ ] [ ]

4. I often feel helpless in dealing with the problems of life.

   Strongly agree (3)  Agree (2)  Disagree (3)  Strongly disagree (4)
   [ ] [ ] [ ] [ ]

5. Sometimes I feel that I'm being pushed around in life.

   Strongly agree (3)  Agree (2)  Disagree (3)  Strongly disagree (4)
   [ ] [ ] [ ] [ ]

6. What happens to me in the future mostly depends on me.

   Strongly agree (3)  Agree (2)  Disagree (3)  Strongly disagree (4)
   [ ] [ ] [ ] [ ]

7. I can do just about anything I really set my mind to do.

   Strongly agree (3)  Agree (2)  Disagree (3)  Strongly disagree (4)
   [ ] [ ] [ ] [ ]
APPENDIX 5.3a

University of Waterloo Occupational Biomechanics Laboratory
Appendices Summary of Measures Used in the Study
APPENDIX 5.3(a):

SUMMARY OF THE BIOMECHANICAL EXPOSURE MEASURES

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Rationale For The Approach

Nachemson (1992), recently has stated:
most case control studies of cross-sectional design that have addressed the mechanical and psychosocial factors influencing LBP, including job satisfaction, have concluded that the latter play a more important role than the extensively studied, mechanical factors. This applies in particular to those 5-10% of patients who are disabled for more than three months and who account for 75-90% of the costs."

Obviously, there are some who feel that the role of the physical demands of worksite tasks in inducing back pain may be overstated. Nachemson cited twelve references to support the notion that psychosocial, rather than biomechanical variables, were emerging as important risk factors for back injury. One of these was the much publicized "Boeing study" (Bigos, et al. 1986:III), a very large retrospective study involving 31,200 employees over a 15 month period. They reported that there was a correlation between incidence of back injuries and poor employee appraisal rating performed by the employee's supervisor within 6 months before the injury. However, the authors (Bigos, et al. 1986:II) reported in another paper that there was a lack of reliable correlation between back injuries and specific job skill codes.

One interpretation of these findings is that estimating physical demands of jobs by skill codes (job titles such as "nurse") is inappropriate because people nominally doing the same job do it quite differently, exposing themselves to differing tissue forces, hence risk of injury Hagberg (1992). Alternatively they have differing tolerance to these forces, resulting in a differing risk of injury. One might also argue that the psychosocial influences affect different people in the same job skill differently, confounding relationships between back injuries and skill code classification. A general conclusion from the observation by Bigos, et al. (1986:II) is that both physical and psychosocial
factors must be effectively monitored if factors affecting risk of musculoskeletal injury are to be properly identified.

Unfortunately, none of the papers listed by Nachemson (1992), nor the prospective Boeing study (Bigos, et al. 1991) included satisfactory biomechanical measures of physical loading. The prospective study appeared to show only job satisfaction to distinguish those who report a back injury from those who did not but only a very small proportion of variance was accounted for by job satisfaction.

Virtually all studies on risk factors that have used objective assessments of the physical demands of the tasks have reported that people who are subjected to combinations of high forces, awkward postures and high repetitions or prolonged efforts are at higher risk of musculoskeletal injury to backs, shoulders and tissues around other joints than those who are not (e.g. Snook, 1978; Frymoyer, et al. 1980; Kelsey and White, 1980; Andersson, 1981; Silverstein et al. 1987; Punnett, et al. 1991; Stock, 1991; Marras, et al. 1993).

The problem is that there are no studies of musculoskeletal disorder risk factors that have included state of the science measures of both biophysical and psychosocial variable. If variables are not properly measured or are not measured at all, whether they are biophysical or psychosocial variables, one cannot expect these variables to show up in multiple regression equations as risk factors. A large scale epidemiological study of well-measured biomechanical and psychosocial variables is badly needed.

This brief paper describes variables that will be included in a case-control study of approximately 400 employees in a large automobile manufacturing company. The cases will comprise 100 people who report back troubles to the plant health office. As currently planned, there will be 100 controls who do the same job as the case, 100 randomly selected controls who are not in pain and 100 randomly selected controls who are working in some pain.

**Estimates Of Physical Exposure To Injury**

Irritation and/or injury to tissue occurs when the energy to which it is exposed exceeds its energy tolerance at a particular moment. The energy may be in mechanical, chemical, thermal or electrical forms. If we restrict the discussion to mechanically induced irritation or injuries, damage will occur to nerve, muscle, tendon, ligament, intervertebral discs and all other tissues when the size of the force to which the tissue is exposed at any instant exceeds the size of the tolerance of that tissue to force at the moment of loading.

Using this concept of injury mechanism, ideally we would argue that tissue loads must be measured and compared against tissue load tolerance information (injury threshold limit values; TLVs) if one is to identify the proportion of variance in tissue injury accounted for by the job physical factors. There are data available on damage thresholds of disc compression forces (e.g. Jager, Luttman and Laurig, 1991), maximum strength of
shoulder, low back, elbow and other joints (e.g. Troup and Chapman, 1969), and proposed limits of various levels of muscle electrical activity above which undesirable levels of fatigue have been shown to occur (e.g. Jonsson, 1982).

For these reasons, our preferred method of assessing the physical demands of tasks, that may be related to injury risk in the workplace, is to obtain estimates of forces on tissues for single physical efforts (peak forces) and the accumulative effect of prolonged and repetitive efforts. We have developed or adopted methods for doing this using computerized biomechanical models and electromyograms. These will be described below. If the acute and accumulated physical demands of tasks within jobs are measured in this way, the specific nature of the job is unimportant. Thus, we have a generic assessment of the task demands. For example, loads on certain tissues of a nurse handling patients can be justifiably compared with those on a steel worker or secretary. The peak loads may well be different but the accumulated loads may be similar. On the other hand, empirical counting of repetitions, or measuring postures on workers in these different occupations who are obviously doing different things with their bodies, becomes more problematic.

A disadvantage of the tissue loading approach is that the methods are time consuming and expensive in equipment and personnel costs to acquire and reduce the data. Therefore, a variety of methods have been reported, all of which, one must assume, are designed to be surrogates of or correlates with tissue forces. Some are self-reporting approaches (questionnaires and ratings of perceived exertion or ratings of perceived discomfort); some are trained observer approaches (check lists); some are objective measures of load weights lifted or push/pull forces exerted; some are objective counts of the numbers of repetitions of movements or duration of static efforts or measures of postures of the arms, hands, torso, etc. (video based or electronic angle measuring devices). A major problem with most, if not all of these methods, is that there have been no or only minimal efforts to validate them against estimates of tissue forces. This is particularly true of questionnaires and check lists (Winkel et al., 1991).

We will use several of these methods simultaneously to capitalize on the different types of information produced and to determine whether there is convergence in the conclusions about risk that emerge from each. We also suggest that validation of any questionnaire must be tested against multiple indicators of tissue forces. It would be dangerous to use an unvalidated questionnaire presumed to measure loads on tissues in a future, large and expensive cohort study.

Methods

The following measures will be used on a representative sub-sample of about 400 workers. To our knowledge, a study of this size using biomechanical estimates of exposure to tissue loading along with subjective measures has never been attempted.
1) Self-administered questionnaire on physical exposure 2) Rating of physical exposure from trained observer(s) 3) Posture of the back and arms using computer aided and video-aided methods 4) Estimates of "acceptable" load weights 5) Biomechanical measures of forces on tissues (2D & 3D computer models) 6) Prolonged measures of heart rate 7) Shift measures of tissue loads; from shoulder and back EMG

These measures are described in greater detail below.

1) Self-administered Questionnaire On Physical Exposure

These instruments are critical to the success of large population based studies because they offer one of the few ways of obtaining information on physical exposure in a cost effective manner. Unfortunately the reliability and especially the validity of most instruments used has not been determined. When this has been tested, the validity of the questionnaire has been only moderate, (Kilbom et al., 1984, as cited in Hagberg, 1992). Baty et al., (1986) used a combination of observation by trained personnel, measured posture and self reported postures. They found poor agreement for many self reported postures and activities and suggested that all such questionnaire be validated against other objective measures before use. These results are similar to those reported by the MUSIC I group, Winkel et al., (1991) who also noted that infrequent activities were reported better than frequent activities.

Other problems of note are the type of scale used; many questionnaires attempt to identify the presence or absence of a risk factor. While this may be satisfactory for exposure/effect investigations, continuous or ordinal scales of measurement would aid in the development of much needed exposure/response relationships. The questionnaire that has been developed usually asks the worker about the nature of his/her job. Interpretation of these responses with respect to tissue loading and job demands is left in the hands of the researchers. This approach is a departure from most other self-reports. Interpretation is computer assisted.

2) Rating Of Physical Exposure From Trained Observer(s)

The content of the rating scales will mirror the information collected by the questionnaire; there are many computer aided approaches to simplify the task of organising and recording the data in the field, such as that described by Winkel et al., (1991) and other authors. Baty et al., (1986) emphasise that training of the observers on standardised activities to achieve acceptable inter-rater reliability is critical to this analysis. This will be done in this study.

3) Posture Analysis Of The Back And Arms

Posture analysis of the back and arms has been central to a large proportion of epidemiologic studies of workplace musculoskeletal disorders. Such studies as those of
Persson and Kilbom (1983) on the neck and shoulder, Keyserling et al., (1987) on the shoulders and back and Punnett et al (1992) on the low back all used video based replay and microcomputer systems to transcribe joint angles. Such studies have shown that posture alone, even without considering loads held in the hands, has some ex–explanatory power for the development of musculoskeletal disorders.

We will use similar methods but have developed improved software; currently available software has limitations in functionality and in the number of motions recordable simultaneously. These problems increase analysis time and reduce the explanatory power of the data. For example, they cannot show simultaneous flexion and side bend easily. Some of the issues which will have to be addressed include the fineness of the categorization made; Kilbom et al., (1986) noted that by recording shoulder flexion in 30° increments they could easily detect inter-individual differences in technique which could increase or decrease the risk of developing musculoskeletal disorders.

Analyses of posture provide such data as proportions of time spent in a given range of movement and the number of posture changes made. The first can be linked to the approximate tissue load on the musculature surrounding the joint in question and the second to the repetitiveness of the task or the presence of postural fixity.

4) Estimates Of "Acceptable" Load Weights

We will use, where applicable, two methods that take into account the duration and frequency of lifting or lowering or pulling and pushing. One is the NIOSH equation proposed by NIOSH (1981) and recently revised, that was produced from a combination of epidemiological, biomechanical, physiological and psychophysical data. The equation is applicable only to single plane (straight forward bends), slow lifts with two hands (no side bending or twists) and is thereby limited, but it is cheap and easy to use. The data are reported as a load weight (kg) adjusted for torso posture, range of motion and frequency of lift.

The other method is Snook Tables based on psychophysical data obtained and reported by Snook (1978, 1991). These data are presented in tables arranged to distinguish among males and females, body posture, size of the load handled and frequency of effort. The output is presented as a load weight or push/pull force reported by the workers to be acceptable (no feelings of &fatigue or risk of injury) to various proportions (deciles) of the samples studied. Based upon epidemiological data, the author claims that back injury incidence would be reduced by two thirds if load weights of tasks were adjusted to be acceptable to 75% of the population. This method is also constrained to a limited number of tasks found in the work place, but it too is cheap and easy to use.

5) Biomechanical Measures Of Forces On Tissues

We have developed two and three dimensional computer models of the human (called
WATBAK and 3DWATBAK) that provide estimates of lumbar disc compression and shear forces and the strength demands on the low back, shoulder, elbow and other joints that are produced by workers during loading handling tasks (Norman 1984; Bone, Norman, McGill and Ball 1990). The models incorporate very current information about spinal mechanics, such as "effective" moment arm lengths, and intervertebral joint shear force reducing abilities of the lumbar musculature if the lordotic curvature is retained by the worker and other features (e.g. McGill and Norman 1986; Potvin, McGill and Norman 1991). The models are used to assess risk of injury to the back or other joints by comparing estimates of tissue forces required during an industrial task with disc compression and shear tolerance and maximum strength reported in the literature. As discussed above, these data can be considered to be injury threshold limit values (TLVs), albeit with knowledge of the limitations of the sources and sample sizes from which they are obtained.

The biomechanical models use worker posture information obtained from video and hand forces in lifts, pushes or pulls, obtained from a portable force transducer. The models can deal with both symmetrical and asymmetrical loading in both static and dynamic tasks. This allows analysis of a wide range of realistic industrial tasks that involve not only straight forward torso bends but lateral bending, torso twisting and combinations of these movements that are common in the workplace. We have used them successfully in the workplace previously (e.g. Norman et al. 1985, 1988).

6) Prolonged Measures Of Heart Rate

One measure of general physiological demand of a task on a worker is the oxygen consumption required. It is impractical to measure oxygen cost directly. Heart rate has been shown to be linearly related to the rate of oxygen consumption, although not without intervening effects of substances such as recent caffeine consumption, excitement and some other factors. These factors notwithstanding, we feel that we would be remiss in not obtaining this type of data, at least for comparative purposes with some data from Sweden that has used heart rate as a global measure of physical demands of some jobs. We will monitor heart rate for a sufficient portion of a shift to obtain an estimate of cardiovascular demand. We will use a Sportstimer device that comprises a band containing two electrodes and a small transmitter that is strapped around the chest and transmits the heart rate to a wrist watch worn by the worker. The data are stored in the watch and are computer analysed by down-loading following the recording session. Williams, et al. (1982) showed that fatigue was inevitable on a group of women who were required to lift weights of various masses at various frequencies, if their heart rates exceeded 140 beats per minute. We know of no studies, such as we propose, that have been able to assess the relationship between an estimate of physiological demand and injury incidence in work place tasks.

7) Shift Measures Of Tissue Loads; From Shoulder And Back EMG
These estimates are the most difficult to make from a technical and modelling perspective. The advent of small microprocessors and solid state memory however provides a solution to the recording of long term muscle activity in manner similar to that currently used for heart rate. We have bought data loggers suitable for recording four channels of EMG for periods of at least four hours continuously. These are lightweight and self contained and provide minimal encumbrance to the subjects.

The use of EMG to estimate low back demands is relatively new; our group has developed a method for estimating the amplitude probability distribution of disc compression during prolonged tasks in field settings (Potvin et al., 1990). We will use this method, which allows estimates of lumbar compression estimates from myoelectric signals from the thoracic area coupled with a number of submaximal calibration postures and loads. Estimates of the degree of asymmetric loading can also be obtained.

The method provides continuous records of absolute load or EMG relative to a voluntary maximum. However, we propose that four measures, the 10th, 50th, 90th percentiles of the amplitude probability distribution function (APDF) as well as the peak or 99th percentile are good measures to characterise exposure of the shoulder and back to loading. In addition, we will incorporate the "gaps" technique suggested by Veiersted (1990) and may incorporate the "exposure variation assessment" (EVA) method proposed by Mathiassen (1991).
References:


APPENDIX 5.3b

University of Waterloo Biomechanics Laboratory Questionnaire for Self-Reporting on the Physical Demands of Work
Ontario Universities Back Pain Study

Biomechanical Measures of Physical Demands at Work

Developed by:
University of Waterloo
Applied Health Sciences
Department of Kinesiology

Today's Date: __/__/___
dd / mm / yy

1. This questionnaire is intended to let you tell us about the physical aspects of your job.

2. We will ask you about the physical loading of jobs you have had in the past.

3. We are particularly interested in the loading on your back. If your current job puts high stresses on your back we will ask you to describe that part of your work.

4. We will also ask you to describe other parts of your work and ask some general questions about your job.

This questionnaire is strictly confidential and will not be shown to anyone in your company or your union. Please answer all questions truthfully and to the best of your ability.
We would like to begin by asking you a few questions about yourself:

1. Birth date: Day______ Month______ Year______
2. Height: ________ feet & inches (or) ________ cm
3. Weight: ________ lbs (or) ________ kg
4. Sex: (CIRCLE NUMBER) 1 Female 2 Male
5. Which hand do you normally write with? (CIRCLE ONE NUMBER)
   1 Right 2 Left 3 Either
6. Considering a 7-day period (a week), how many times on the average do you do the following kinds of exercise for more than 15 minutes during your free time? (WRITE IN NUMBER) TIMES PER WEEK
   a) STRENUEOUS EXERCISE (HEART BEATS RAPIDLY)
      (examples: running; jogging; hockey; football; soccer; squash; basketball; cross country skiing; judo; roller skating; vigorous swimming; vigorous long distance biking)
   b) MODERATE EXERCISE (NOT EXHAUSTING)
      (examples: fast walking; baseball; tennis; easy bicycling; volleyball; badminton; alpine skiing; popular dancing; easy swimming)
   c) MILD EXERCISE (MINIMAL EFFORT)
      (examples: yoga; archery; fishing; bowling; horseshoes; golf; snowmobiling; easy walking)
7. Considering a 7-day period (a week), during your leisure time, how often do you engage in any regular activity long enough to work up a sweat (heart beats rapidly)? (WRITE IN NUMBER) TIMES PER WEEK
8. Do you lift young children (age 0 - 5 years) or elderly persons with mobility problems at home?
   1 Yes 2 No
9. How many packs of cigarettes do you smoke (1 pack = 25 cigarettes)? (CIRCLE ONE NUMBER)
   1 Never Smoked
   2 I quit smoking
   3 Less than a pack a day
   4 About a pack a day
   5 More than a pack a day
   6 More than two packs a day
10. How do you usually get to work? (CIRCLE ONE NUMBER)
    1 Car 2 Bus
    3 Train 4 Walk
    5 Bicycle 6 Other: ______________________
11. On average, how long does it usually take you to get to work? (CIRCLE ONE NUMBER)
    1 Less than 15 min 2 15-30 min
    3 30-45 min 4 45-60 min
    5 Over 1 hour

We would like to get some information about your current job. (Use the examples to help you
answer the next few questions.)

<table>
<thead>
<tr>
<th>For Repetitive Jobs...</th>
<th>For Non-Repetitive Jobs...</th>
</tr>
</thead>
</table>

**EXAMPLE 1:**
What is your present job?
Tire maintenance

List the tasks you do on your job:
1. pick up 1 tire and place on car
2. hand start 5 nuts
3. run 5 nuts with power tool
4. visually inspect

**EXAMPLE 2:**
What is your present job?

List the tasks you do on your job:
1. Perform preventative maintenance on equipment
2. Perform emergency repairs
3. Schedule regular maintenance

12. What is your present job?

13. a) List the tasks you do on your job.

1. 
2. 
3. 
4. 
5. 
6. 

b) On a scale of 0 to 10 we would like you to tell us how heavy each task is on your back.

0 1 2 3 4 5 6 7 8 9 10
Very light Very heavy

Task 1 
Task 2 
Task 3 
Task 4 
Task 5 
Task 6 

*(WRITE IN NUMBER FOR EACH TASK LISTED ABOVE.)*
c) We would like you to tell us how long it takes you to do each of these tasks once.

<table>
<thead>
<tr>
<th>Task</th>
<th>Minutes</th>
<th>Seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 3</td>
<td></td>
<td></td>
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<tr>
<td>Task 4</td>
<td></td>
<td></td>
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<tr>
<td>Task 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please give your best estimate for each task you identified.

d) We would like you to tell us how many times you do each task per shift.

<table>
<thead>
<tr>
<th>Task</th>
<th>Times</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1</td>
<td></td>
</tr>
<tr>
<td>Task 2</td>
<td></td>
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<tr>
<td>Task 3</td>
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<td>Task 4</td>
<td></td>
</tr>
<tr>
<td>Task 5</td>
<td></td>
</tr>
<tr>
<td>Task 6</td>
<td></td>
</tr>
</tbody>
</table>

For each task you identified please give your best estimate of how many times you do this task on an "average shift".

14. In which task(s) do you twist your back (as in the picture)? (CHECK ALL WHICH APPLY)

- Task 1
- Task 2
- Task 3
- Task 4
- Task 5
- Task 6
- None

(Side View)

15. In which task(s) do you bend sideways further than indicated in the picture? (CHECK ALL WHICH APPLY)

- Task 1
- Task 2
- Task 3
- Task 4
- Task 5
- Task 6
- None

(Front View)

16. a) In which task(s) do you bend forward further than indicated in the picture? (CHECK ALL WHICH APPLY)

- Task 1
- Task 2
- Task 3
- Task 4
- Task 5
- Task 6
- None

(Side View)
- ABOUT YOUR CURRENT JOB -

b) In which task(s) do you bend forward further than indicated in the picture? *(CHECK ALL WHICH APPLY)*

- Task 1 [ ]
- Task 2 [ ]
- Task 3 [ ]
- Task 4 [ ]
- Task 5 [ ]
- Task 6 [ ]
- None [ ]

17. In which task(s) do you bend backward further than indicated in the picture? *(CHECK ALL WHICH APPLY)*

- Task 1 [ ]
- Task 2 [ ]
- Task 3 [ ]
- Task 4 [ ]
- Task 5 [ ]
- Task 6 [ ]
- None [ ]

18. In which task(s) do you work with your arms over your head? *(CHECK ALL WHICH APPLY)*

- Task 1 [ ]
- Task 2 [ ]
- Task 3 [ ]
- Task 4 [ ]
- Task 5 [ ]
- Task 6 [ ]
- None [ ]

19. In which task(s) do you lift heavy parts? *(CHECK ALL WHICH APPLY)*

- Task 1 [ ]
- Task 2 [ ]
- Task 3 [ ]
- Task 4 [ ]
- Task 5 [ ]
- Task 6 [ ]
- None [ ]

20. In which task(s) do you squat? *(CHECK ALL WHICH APPLY)*

- Task 1 [ ]
- Task 2 [ ]
- Task 3 [ ]
- Task 4 [ ]
- Task 5 [ ]
- Task 6 [ ]
- None [ ]
21. a) Do any of the tasks in your job require you to remain in postures for an extended period which become uncomfortable to your back? (CIRCLE ONE) Which task? If more than one pick the one where you feel the most discomfort. (INSERT TASK NUMBER)

1 Yes, TASK #______.
2 No --> GO TO Q22.

b) Refer to the pictures on the next page (marked "BACK") for this question. Which of these pictures best describes your back position for the above task?

My back position for this task is: _____. (PICK A NUMBER FROM THE "BACK" PICTURES)

c) How long do you hold this position? (CIRCLE ONE)

1 0-2 seconds
2 2-5 seconds
3 5-10 seconds
4 10-30 seconds
5 30-60 minutes
6 Over 1 minute

22. a) Which task is heaviest on your back? (CIRCLE ONE)

1 Task #1
2 Task #2
3 Task #3
4 Task #4
5 Task #5
6 Task #6

b) Please describe the physical components of this task:

________________________________________________________________________

________________________________________________________________________

Imagine you are doing the task which you identified as heaviest on your back in question 22. The following questions all apply to the heaviest instant of that task (try to imagine a single photo or freeze-frame of the moment in the task which is most stressful on your back).

23. a) Refer to the pictures on the next page (marked "BACK") for this question. Which of these pictures best describes your back posture at the heaviest instant of the task chosen in Q22. (The heaviest instant in the task is the single point where you feel the most force/load on your body.)

At the heaviest instant of this task my back position is: _____

(PICK A NUMBER FROM THE "BACK" PICTURES ON THE NEXT PAGE)

Pick ONE (1) picture which BEST MATCHES your posture during the most stressful instant for your back.
BACK
[For questions 21(b) and 23(a) identify the picture which BEST describes the position of your back]
(Ignore the positions of your arms and legs)

1. Leaning back slightly

2. Back straight

3. Leaning forward slightly

4. Leaning sideways

5. Twisted

6. Fully bent over

7. Leaning sideways

8. Twisted

9. Twisted and bent

10. Sitting, leaning back

11. Sitting

12. Sitting, leaning forward

13. Sitting twisted

14. Lying down
b) At this instant of the task, where do you hold your arms? (FOR EACH ARM: SELECT THE POSITION THAT MOST CLOSELY APPLIES AND CIRCLE THE APPROPRIATE NUMBER.)

**SIDE VIEW:**

**LEFT**
- Arm vertical
- Arm raised
- Arm horizontal
- Arm lowered
- Arm straight down

**RIGHT**
- Arm vertical
- Arm raised
- Arm horizontal
- Arm lowered
- Arm straight down

**ELBOW ANGLE:**
- Elbow slightly bent
- Elbow bent midway
- Elbow fully bent
- Arm outstretched (straight)

**24.** How heavy is the load that you handle when you are in this posture? (CIRCLE ONE NUMBER)

1. No Load -> (GO TO Q27)
2. Light (0-11 lbs or 0-5 kg)
3. Medium (11-25 lbs or 5-11 kg)
4. Moderately Heavy (25-40 lbs or 11-18 kg)
5. Heavy (40-50 lbs or 18-23 kg)
6. Extremely Heavy (over 50 lbs or over 23 kg)

**25.** With which hand do you handle the load at the heaviest instant of this task? (CIRCLE ONE NUMBER)

1. Right hand only
2. Mostly right hand
3. Both hands equally
4. Mostly left hand
5. Left hand only

**26.** At this instant in this task which of the following BEST describes the direction in which you are exerting force? (CIRCLE ONE NUMBER)

1. Lift / lower / pushing up / pulling up
2. Pushing down / pulling down
3. Pushing forward
4. Pulling back
27. At what point in your shift do you usually perform this task? (CIRCLE ONE NUMBER)
   1. Throughout
   2. Varies
   3. Beginning
   4. Middle
   5. End

28. What are you doing just before this task? (CIRCLE ONE NUMBER)
   1. Not sitting
   2. Sitting for more than 15 minutes
   3. Sitting for less than 15 minutes

The next section of this questionnaire consists of some general questions about your job.

29. Do you feel any discomfort or pain (either at work or at home) that is related to your job?
   1. Yes (CONTINUE ON WITH THIS QUESTION)
   2. No -> GO TO Q30.

Please use the picture and the scales provided to tell us where the pain is and how severe and frequent it is.

a) I feel the most pain in area: __________ (PICK A LETTER)
   My pain level in this area is: __________ (PICK A NUMBER)
   The frequency of this pain is: __________ (PICK A NUMBER)
   What are you doing when you feel this pain?
   __________________________________________
   __________________________________________
   __________________________________________

b) □ I feel no other pain or discomfort
   -> If TRUE GO TO Q30.

c) My second most painful area is: __________ (PICK A LETTER)
   My pain level in this area is: __________ (PICK A NUMBER)
   The frequency of this pain is: __________ (PICK A NUMBER)
   What are you doing when you feel this pain?
   __________________________________________
   __________________________________________
   __________________________________________

Pain Scale

Frequency of Pain

Never	Sometimes	Always
30. Do you exert much muscular effort on your job?
   1. Yes (CONTINUE ON WITH THIS QUESTION)
   2. No → GO TO Q31.

What two parts of your body do you work the hardest during a typical shift? (From the picture provided, please identify the body part with which you make the most effort, and rate your effort for that location.)

a) I exert the most effort in area:
   __________ (PICK ONE LETTER ONLY)
   My effort level in this area is:
   __________ (PICK A NUMBER)

   What task are you doing when you exert this effort?
   ____________________________________________
   ____________________________________________
   ____________________________________________
   ____________________________________________
   ____________________________________________
   ____________________________________________

b) ☐ don't exert any other muscular effort at work.
   --> If TRUE GO TO Q31.

c) I exert the second most effort in area: __________ (PICK A LETTER)
   My effort level in this area is: _____ (PICK A NUMBER)

   What task are you doing when you exert this effort
   ____________________________________________
   ____________________________________________
   ____________________________________________
   ____________________________________________
   ____________________________________________
- ABOUT YOUR CURRENT JOB -

31. How long have you been working at your present job? (CIRCLE ONE NUMBER)
   1. Less than 1 year
   2. 1-2 years
   3. 2-5 years
   4. 5-10 years
   5. 10-15 years
   6. Over 15 years: __________ years

32. How many hours do you usually work in a shift? (CIRCLE ONE NUMBER)
   1. Over 14 hours
   2. 14 hours
   3. 13 hours
   4. 12 hours
   5. 11 hours
   6. 10 hours
   7. 9 hours
   8. 8 hours
   9. 7 hours
   10. 6 hours
   11. 5 hours
   12. 4 hours
   13. Under 4 hours

33. How many shifts do you usually work in a week? (CIRCLE ONE NUMBER)
   1. I don't work every week
   2. 1 shift/week
   3. 2 shifts/week
   4. 3 shifts/week
   5. 4 shifts/week
   6. 5 shifts/week
   7. 6 shifts/week
   8. 7 or more shifts/week

34. How many scheduled breaks (e.g., lunch & coffee) do you get during an average shift? (CIRCLE ONE NUMBER)
   1. I don't have scheduled break times
   2. 1 break/shift
   3. 2 breaks/shift
   4. 3 breaks/shift
   5. 4 breaks/shift
   6. 5 breaks/shift
   7. 6 breaks/shift
   8. 7 or more breaks/shift

35. How much scheduled break time (e.g., lunch & coffee) do you get in total over a shift? (CIRCLE ONE NUMBER)
   1. I don't have scheduled break time
   2. Less than ½ hour
   3. ½ hour to 1 hour
   4. 1 hour to 1½ hours
   5. Over 1½ hours
36. How much time do you spend sitting at work? (do not include coffee & lunch breaks)  (CIRCLE ONE NUMBER)

1  I don't sit at work
2  0-2 hours (some sitting)
3  2-4 hours (often sit)
4  4-6 hours
5  6-8 hours
6  Over 8 hours

37. During a typical work shift, how often do you stand up from a seated posture?  (CIRCLE ONE NUMBER)

1  I don't sit at work
2  Less than once per hour
3  1-2 times per hour
4  3-4 times an hour
5  Every ten minutes
6  Every five minutes
7  Every minute

38. How much time do you spend standing at work? (*standing" means not walking further than a few steps)  (CIRCLE ONE NUMBER)

1  I don't stand at work
2  0-2 hours (some standing)
3  2-4 hours
4  4-6 hours
5  6-8 hours
6  Over 8 hours

39. What is the floor surface where you usually work?  (CIRCLE ONE NUMBER)

1  Hard (e.g., concrete)
2  Soft (e.g., carpet)
3  "Anti-Fatigue" Matting
4  Sloped surface (e.g., ramps)
5  Slippery surface
6  Other: ______________________

40. How often are you surprised by an unexpected load? (e.g., a load is heavier or lighter than you expected, a load gives way suddenly, you must catch a load before it falls, or you slip, trip etc.)  (CIRCLE ONE NUMBER)

1  I am never surprised by an unexpected load
2  1 time/month
3  1 time/week
4  2-3 times/week
5  3-7 times/week
6  1 time/shift
7  2-3 times/shift
8  Over 3 times/shift

41. Please rate the usual temperature for this season in your work environment:  (CIRCLE ONE NUMBER)

0  1  2  3  4  5  6  7  8  9  10
Very cold  Very hot
42. Please rate the usual humidity in your work environment: (CIRCLE ONE NUMBER)

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very dry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Very humid</td>
</tr>
</tbody>
</table>

43. a) On average, how often are you physically jolted at work? (like driving over a pothole or having to pull quickly against a stationary object) (CIRCLE ONE NUMBER)

<table>
<thead>
<tr>
<th>1</th>
<th>I am not physically jolted at work (GO TO Q44)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Less than once per hour</td>
</tr>
<tr>
<td>3</td>
<td>1-2 times per hour</td>
</tr>
<tr>
<td>4</td>
<td>3-4 times an hour</td>
</tr>
<tr>
<td>5</td>
<td>Every ten minutes</td>
</tr>
<tr>
<td>6</td>
<td>Every five minutes</td>
</tr>
<tr>
<td>7</td>
<td>Every minute</td>
</tr>
<tr>
<td>8</td>
<td>Every 30 seconds or more</td>
</tr>
</tbody>
</table>

b) Please rate the usual severity of this jolting on the 0 to 10 scale provided. (CIRCLE ONE NUMBER)

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>No jolting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Extreme jolting</td>
</tr>
</tbody>
</table>

44. a) During an average shift what is the total time you experience vibration to your hands or arms? (CIRCLE ONE NUMBER)

<table>
<thead>
<tr>
<th>1</th>
<th>I do not experience vibration to my hands or arms (→ GO TO Q45)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0-2 hours total</td>
</tr>
<tr>
<td>3</td>
<td>2-4 hours total</td>
</tr>
<tr>
<td>4</td>
<td>4-6 hours total</td>
</tr>
<tr>
<td>5</td>
<td>6-8 hours total</td>
</tr>
<tr>
<td>6</td>
<td>Over 8 hours total</td>
</tr>
</tbody>
</table>

b) Please rate the intensity of this vibration on the 0 to 10 scale provided. (CIRCLE ONE NUMBER)

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>No vibration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Extreme vibration</td>
</tr>
</tbody>
</table>

45. a) During an average shift what is the total time you experience vibration to your feet or back? (CIRCLE ONE NUMBER)

<table>
<thead>
<tr>
<th>1</th>
<th>I do not experience vibration to my feet or back (GO TO Q46)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0-2 hours total</td>
</tr>
<tr>
<td>3</td>
<td>2-4 hours total</td>
</tr>
<tr>
<td>4</td>
<td>4-6 hours total</td>
</tr>
<tr>
<td>5</td>
<td>6-8 hours total</td>
</tr>
<tr>
<td>6</td>
<td>Over 8 hours total</td>
</tr>
</tbody>
</table>

b) Please rate the intensity of this vibration on the 0 to 10 scale provided. (CIRCLE ONE NUMBER)

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>No vibration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Extreme vibration</td>
</tr>
</tbody>
</table>
46. For each of the body areas listed, please rate the overall risk of injury you associate with your job.

(CIRCLE ONE NUMBER FOR EACH BODY PART)

<table>
<thead>
<tr>
<th>Body Area</th>
<th>NO RISK</th>
<th>EXTREME RISK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>Neck</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>Shoulder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>Forearm or Hand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>0 1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
</tbody>
</table>

47. a) JOB #1: (Your current job)

Trade or Job title: ________________________________

Describe your job: __________________________________________________________

Starting date: month _______ year ________

On a 0-10 scale, please rate how physically hard (heavy) your current job is on your back. (CIRCLE ONE NUMBER)

0 1 2 3 4 5 6 7 8 9 10
Very light Very heavy

b) JOB #2: (Your last job)

Trade or Job title: ________________________________

Description of tasks: __________________________________________________________

Starting in: year ________ Number of years at this job: ______

On a scale from 0-10, please rate how physically hard (heavy) this job was on your back. (CIRCLE ONE NUMBER)

0 1 2 3 4 5 6 7 8 9 10
Very light Very heavy
b) JOB #3:
Trade or Job title: ____________________________________________________________
Description of tasks:  _______________________________________________________

 Starting in: year _________  Number of years at this job: __________

On a scale from 0-10, please rate how physically hard (heavy) this job was on your back. (CIRCLE ONE NUMBER)

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very light</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>Very heavy</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b) JOB #4:
Trade or Job title: ____________________________________________________________
Description of tasks:  _______________________________________________________

 Starting in: year _________  Number of years at this job: __________

On a scale from 0-10, please rate how physically hard (heavy) this job was on your back. (CIRCLE ONE NUMBER)

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very light</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>Very heavy</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b) JOB #5:
Trade or Job title: ____________________________________________________________
Description of tasks:  _______________________________________________________

 Starting in: year _________  Number of years at this job: __________

On a scale from 0-10, please rate how physically hard (heavy) this job was on your back. (CIRCLE ONE NUMBER)

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very light</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>Very heavy</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

48. a) Did you ever permanently change jobs because you were having too much back pain? (CIRCLE ANY THAT APPLY)

<table>
<thead>
<tr>
<th>1</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>No --&gt; (GO TO Q49)</td>
</tr>
</tbody>
</table>

b) If YES, please indicate which job or jobs you had to leave. (CIRCLE ONE NUMBER)

<table>
<thead>
<tr>
<th>1</th>
<th>JOB #2 (Last job)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>JOB #3</td>
</tr>
<tr>
<td>3</td>
<td>JOB #4</td>
</tr>
<tr>
<td>4</td>
<td>JOB #5</td>
</tr>
</tbody>
</table>
49. a) Was your work history interrupted for any period of time equal to or longer than one year (example to return to school, raise a child, etc? (CIRCLE ONE NUMBER)

1  Yes
2  No -> (GO TO Q50)

b) If YES, please state the length and dates for the interruption.

Total duration: _______ (years)
Starting in 19__ and continuing until 19__.

50. What is the combined (total) number of years that you have spent working fulltime?

Total years worked: _______

51. On a scale from 0 to 10, how would you rate the overall physical demands of the jobs from your entire work history? (CIRCLE ONE NUMBER)

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very light</td>
<td>Very heavy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

52. a) Did you have an injury or injuries at your last job for which you required time off work? (CIRCLE ONE NUMBER)

1  Yes - one injury
2  Yes - one injury but with re-occurrences
3  Yes - more than one injury
4  No -> (GO TO Q53)

b) If YES, what part(s) of your body did you injure?

(PLACE A TICK ✓ IN ANY BOX THAT APPLIES)

<table>
<thead>
<tr>
<th>One Occurrence</th>
<th>More than 1 Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Back</td>
<td></td>
</tr>
<tr>
<td>Upper Back</td>
<td>✓</td>
</tr>
<tr>
<td>Neck</td>
<td>✓</td>
</tr>
<tr>
<td>Right Shoulder</td>
<td>✓</td>
</tr>
<tr>
<td>Left Shoulder</td>
<td>✓</td>
</tr>
<tr>
<td>Both Shoulders</td>
<td>✓</td>
</tr>
<tr>
<td>Right Forearm or Hand</td>
<td></td>
</tr>
<tr>
<td>Left Forearm or Hand</td>
<td></td>
</tr>
<tr>
<td>Both Forearms or Hands</td>
<td></td>
</tr>
<tr>
<td>Other: ______________</td>
<td></td>
</tr>
</tbody>
</table>

53. We realize that everything may not have been covered in this questionnaire. If you have any other concerns about the physical loading of your job please provide details.

________________________________________
________________________________________

***** THANK YOU FOR YOUR TIME! *****
APPENDIX 5.3c

The Physical Loading Report
As part of the Ontario Universities Back Pain Study, physical loading of this job was measured. The results are summarized below.

Tasks Evaluated (If more than 5 tasks, list overleaf):

<table>
<thead>
<tr>
<th>Task</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1:</td>
<td></td>
</tr>
<tr>
<td>Task 2:</td>
<td></td>
</tr>
<tr>
<td>Task 3:</td>
<td></td>
</tr>
<tr>
<td>Task 4:</td>
<td></td>
</tr>
<tr>
<td>Task 5:</td>
<td></td>
</tr>
</tbody>
</table>

### Physical Demands Estimates

<table>
<thead>
<tr>
<th>Task Loads</th>
<th>Job 1</th>
<th>Job 2</th>
<th>Job 3</th>
<th>Job 4</th>
<th>Job 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>push / pull / lift (Kg)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

### WATBAK Spine Loading Estimates

<table>
<thead>
<tr>
<th></th>
<th>Job 1</th>
<th>Job 2</th>
<th>Job 3</th>
<th>Job 4</th>
<th>Job 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. compressive force (N)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Max. shear force (N)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Max. moment (N-m)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

### NIOSH

<table>
<thead>
<tr>
<th></th>
<th>Job 1</th>
<th>Job 2</th>
<th>Job 3</th>
<th>Job 4</th>
<th>Job 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Permissible Limit</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

### Snook

<table>
<thead>
<tr>
<th></th>
<th>Job 1</th>
<th>Job 2</th>
<th>Job 3</th>
<th>Job 4</th>
<th>Job 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% capable</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

### Heart Rate

<table>
<thead>
<tr>
<th></th>
<th>Job 1</th>
<th>Job 2</th>
<th>Job 3</th>
<th>Job 4</th>
<th>Job 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest heart rate (beats/min)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Work heart rate (beats/min)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

### Back Posture

<table>
<thead>
<tr>
<th></th>
<th>Job 1</th>
<th>Job 2</th>
<th>Job 3</th>
<th>Job 4</th>
<th>Job 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe flexion (% time &gt; 45° bend)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Twist (% time &gt; 20° twist)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Lateral bend (% time &gt; 20° bend)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

### Whole Body Vibration - ISO weighted

<table>
<thead>
<tr>
<th></th>
<th>Job 1</th>
<th>Job 2</th>
<th>Job 3</th>
<th>Job 4</th>
<th>Job 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO weighted (m/s²)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

The measures used are specific to the low back research project being conducted and do not constitute a complete ergonomic analysis of the worksite.

- [ ] Further study not indicated
- [ ] Further study required

Report Compiled By:
Ontario Universities Back Pain Study

As part of the Ontario Universities Back Pain Study, the physical loading of this job was measured. The measures used are specific to the low back research project being conducted and do not constitute a complete ergonomic analysis of the worksite. The levels of values suggesting further analysis are subject to substantial variation and should not be interpreted as precise cutoff values. Analysis methods that do not apply to the job studied are marked n/a.

Description & Interpretation of Loading Measures

Maximum Loads
This is the heaviest load handled by the worker for each task and is listed in kilograms for both. In addition, the direction of force is indicated by L (Pull), H (Push), T (Lift), or Y (cary).

WATBAK Spine Loading Estimates
WATBAK is a computer-based model which can produce estimates of the forces on the spine based on a person's posture and the force they are exerting. The WATBAK values listed here include the vertical crush force on the spine (compression), the horizontal force on the spine (shear), and the torque force exerted by the spine (moment). WATBAK levels of spinal force suggesting further analysis are values over 8000N of compression, 1000N of shear, or 400 Nm lumbar moment.

Heart Rate
The participants resting heart rate is measured off the line, work heart rate is measured while the worker is actively doing their regular job, and waking heart rate is measured while the worker is waiting for the next job. Levels of heart rate suggesting further analysis include either a work heart rate consistently greater than 130 beats per minute in both work and waking phases, or an increase of over 20 beats per minute from rest to work levels.

Back Posture
Back Posture data are categorized and tabulated from the works body positions as they do their work. These numbers represent the amount of time the worker is bent forwards, backwards, to the side, or is working with their back twisted. Postures suggesting further analysis arise when more than 50% of the work time is spent in severe flexion (bent forwards more than 45°), with a twisted back (twist more than 20°), or lateral bending (side bend greater than 20°).

NIOSH
The National Institute of Occupational Safety and Health's (USA) equation can be used to calculate load guidelines for manual lifting. The maximum permissible limit (MPL) calculated here only applies to smooth, symmetrical, two-handed lifts when the worker's body is unsupported. Many GM jobs do not fit this description; these are marked n/a. NIOSH levels suggesting further analysis exist when workers are lifting more weight than the MPL indicates.

Snook
The Snook tables are based on human perception of the loading resulting from manual materials handling. The value recorded indicates the load level at which 50% of the subjects felt they were able to perform the job comfortably. These tables apply to situations where workers are using tote boxes with good hand-holds and have level and secure footing. Many GM jobs do not fit this description; these are marked n/a. Snook levels suggesting further analysis exist when loads exceed the 50% capable value given in the Snook tables.

Whole Body Vibration
Vibration measures are taken if the worker is exposed to vibration through the floor or from a seat. If the worker is not exposed to these types of vibration this measure will not be conducted and will be noted as n/a.

Questions
Questions should be directed to the General Motors designated contact:
I. Lamb, Truck Plant Safety Dept. x7081.

Takes from PICKUP NEWS Tuesday, February 6th, 1984:
Study on back pain begins today

Researchers from universities will conduct a small-scale study in Pick-Up News over the next few weeks and have elected to perform the study questionnaire and verify that the physical stress as a result of work is being recorded. The researchers are not in a position to start gathering data for the actual study. They will be approaching people reporting back pain and indicating they will take part in the study. As well, for comparison purposes, the researchers will ask a random sample of the rest of the workforce to participate in the study.

No preliminary results are available now, but the researchers are consulting with people in the General Motors, the University of Toronto and the University of Waterloo. The research is led by Dr. John Frank from the University of Toronto, a physician specializing in the fields of medicine. The researchers include Dr. John Frank from the University of Waterloo, Dr. Larry Shannon from the University of Toronto, and Dr. Brian Reisman from the University of Waterloo.

The research is funded by the Workplace Safety and Health Board and the University of Waterloo. As well, the researchers are looking to start gathering data for the actual study. They will be approaching people reporting back pain and indicating they will take part in the study. As well, for comparison purposes, the researchers will ask a random sample of the rest of the workforce to participate in the study.

The focus of the study is on back pain and will be conducted in the following manner. The researchers are consulting with people in the General Motors, the University of Toronto and the University of Waterloo. The research is led by Dr. John Frank from the University of Toronto, a physician specializing in the fields of medicine. The researchers include Dr. John Frank from the University of Waterloo, Dr. Larry Shannon from the University of Toronto, and Dr. Brian Reisman from the University of Waterloo.

Said Dr. Frank: "We look forward to our involvement with the workforce in GM. They have the opportunity to help themselves, their co-workers and the many other people with back pain."
APPENDIX 5.4

Physical Exam Data Collection Sheet
1. Restricted Range

Finger-floor distance, ____ in.
Use a 6" block to record negative values.

2. straight Leg Raising

Right ____°: Left ____°
(do not round to nearest 5°)
Mark location of pain, if experienced.
Diagram shows ____°?

3. Suck-in Sit-ups

Safety: The exercise must be painless.
The spine must form a smooth, C-shaped curve, with no movement at the belt line. Begin with a strong pelvic tilt, then tilt the head forward until the chin is on the chest. Smoothly bring the elbows to the knees, and lay back pushing the belt line down.

4. Grip Strength

Right     Left

5. Reflexes

Score: 0 to 4; normal 2.

Site     Right     Left
Knee (L3-4)  ......  ......  
Hamstring (LS)  ......  ......  
Ankle (S1)  ......  ......  

6. Tenderness

Score: nontender = 0, tender = 1

<table>
<thead>
<tr>
<th>Site</th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezius</td>
<td>......</td>
<td>......</td>
</tr>
<tr>
<td>2nd rib</td>
<td>......</td>
<td>......</td>
</tr>
<tr>
<td>Elbow</td>
<td>......</td>
<td>......</td>
</tr>
<tr>
<td>Gluteus</td>
<td>......</td>
<td>......</td>
</tr>
<tr>
<td>Trochanter</td>
<td>......</td>
<td>......</td>
</tr>
<tr>
<td>Above knee</td>
<td>......</td>
<td>......</td>
</tr>
<tr>
<td>Below knee</td>
<td>......</td>
<td>......</td>
</tr>
<tr>
<td>Instep</td>
<td>......</td>
<td>......</td>
</tr>
</tbody>
</table>

Total number of tender sites: ____
APPENDIX 5.5

Study Consent Forms
CONSENT FORM
ONTARIO UNIVERSITIES BACK PAIN STUDY

A group of researchers from the University of Toronto, McMaster University, and the University of Waterloo is interested in learning more about low-back pain occurring in the workplace. Information collected in this study may help to prevent these injuries. The researchers also hope to improve the care and treatment of people who have been injured at work. The study is being funded by the Institute for Work & Health, which is not part of the Ontario Workers' Compensation Board (WCB). The research unit at the Institute is directed by scientists who are university professors and are not employees of the WCB. They are in no way connected to the claims process at the WCB.

A. Questionnaires

If I agree to participate in this study, I understand that:

1. I will be in contact with a trained research interviewer concerning back pain and the factors that may affect it;

2. I may be interviewed up to five times over a period of six months in order to complete and return a set of questionnaires;

B. Physical Examination

I understand that an examination of my lower back will be conducted by a trained interviewer. This involves six simple tests often done on back pain patients.

These will be:

1. a test of my grip strength (to measure overall fitness) which involves squeezing as hard as possible a pressure sensitive bag;

2. measuring the distance between my fingers and the floor when I bend over without bending my knees;

3. testing my knee, ankle, and hamstring reflexes with a reflex hammer;

4. lying on my back and raising each of my legs as high as I can without pain;
5. the application of modest pressure to my neck, collarbone area, arms, hips, legs and feet to test for tenderness;

6. modified sit-ups using a back support.

I understand that:

1. participation in each part of the study is voluntary;

2. apart from the analysis of the physical loads of my job, any information I provide will be treated as confidential, will not be given to the company, the union(s), the WCB or anyone outside the research team, and will be reported in ways which ensure that I cannot be identified;

3. decisions I make regarding this study will have no affect on my medical treatment or my work;

4. decisions I make regarding this study will not affect my sickness or compensation (WCB) benefits or the adjudication of any WCB claim I have pending.

5. I may refuse to complete any tests which are of concern to me;

6. I may ask the research staff to stop any test which causes me discomfort.

7. the person administering the physical examination will collect information about my back and will not be a physician who can make a diagnosis or prescribe treatment for me.

(Signature of Participant)  (Signature of Interviewer)

(Date)

For further information please contact
Sue Ferrier, Study Coordinator, at 1-800-661-2079
CONSENT FORM - RELEASE OF MEDICAL INFORMATION
ONTARIO UNIVERSITIES BACK PAIN STUDY

I am participating in a six month study with researchers from the University of Toronto, McMaster University, and the University of Waterloo, who are interested in learning more about the causes of low-back pain at work. In order to help the researchers understand what types of tests and treatments are currently used for people with low-back pain, I agree that these researchers may request excerpts from my medical files concerning aspects of my health care directly related to back pain. These may include checking my records to verify tests ordered and confirming treatments prescribed for my low-back pain. I agree that this information can be released to these researchers up to one year from the date of signing this consent form.

I understand that this information will be treated as confidential and that my name will not appear in any report as a result of my participation. I understand that my files will not be released to any other parties or agencies without my express written consent to do so. I hereby authorize the following physician investigators (and their direct designates) to request information from my doctor(s) regarding my back problems current and past: Dr. John Frank and Dr. Claire Bombardier.

(Signature of Participant)                                                  (Signature of Interviewer)

______/______
(Date)

For further information please contact
Sue Ferrier, Study Coordinator, at 1-800-661-2079
INFORMATION SHEET

Department of Kinesiology
University of Waterloo

Study Title: Biomechanical Measures of Exposure to Occupational Injury

Conducted By: R.W. Norman, and R. Wells

Contact: Patrick Neumann (519) 885-1211, ext. 6376
G.M. Site (905) 644-3974

Purpose:

The social and financial costs of industrial back and over-use injuries to the back, wrist, fingers and other body regions are high and continuing to rise. While many different measures of work site injury risk have been proposed in the past there has been little or no work done to validate these measures. This project is intended to provide an in-depth analysis of the most common methods used to evaluate "injury risk" in the workplace. This will allow the development of more reliable and valid measures that can be used to assess the risk of injury - before the injury occurs.

We are trying to find out what parts of your job, if any, may increase your risk of injury. To do this it is necessary to find out the size of forces your job puts on your muscles, low back discs, and other parts of your body.

The Study:

You will be asked to work at your normal job while you undergo one or more and possibly all, of the following:

Work on your normal job at a normal work pace while:

1. You are filmed and/or videotaped.
2. Electrical activity from your muscles is obtained by taping small sensors to the skin over the muscles on your back, under your clothing. To simplify this process we ask that you not wear excessively tight clothing. You do not feel discomfort. The small electrical signal produced by your muscles goes from these muscles to a small recording device strapped around your waist.

To assess the demands of your job we must compare them with the force you can produce with your muscles voluntarily. These efforts are similar to those you might produce during exercise or while moving something at home and involve holding a moderate weight (10 kg or less) in your hands while bending at the waist. At the end of the measurement period you will be asked to hold this weight for up to two minutes or until you want to stop.

3. Your heart beat is recorded using a strap around your chest and a special recording wrist watch.

4. Trained researchers, who are interested in the way you move while working, will observe you as you work and make notes.

5. You are asked to complete questionnaires that include questions about challenging aspects of your job and your recollection of demands of previous jobs.

You may be asked to work for only a few minutes or up to a full shift with usual breaks for coffee and lunch. You will not be asked to work any harder than you normally do.

If you are not currently doing your normal job due to pain, illness or injury, you should not participate in this study. There is always a risk of muscle, joint or other injury in any physical work. The risks in this study are no higher than in your normal work or in an exercise program or recreational activity that requires brief maximum muscular efforts. Some individuals may experience a mild skin irritation from the tape used to attach the sensors to your skin. This is similar to irritation that may be caused by a band-aid and should fade just as quickly.

You may experience some joint stiffness or muscle soreness one or two days following the experiments if you do some unaccustomed work. This is normal and usually disappears in a few days. The portable part of our electrical recording system is battery operated and isolates you from the main electrical lines.
CONSENT FOR BIOMECHANICAL MEASURES

I have read and understood the information presented about the procedures and risks involved in this study and have received satisfactory answers to questions related to this study. I understand that, apart from the analysis of the physical loads of my job, any information I provide will be treated as confidential and not shared with the company, the union(s), the WCB or anyone outside the research team. Apart from the analysis of the physical loads of my job, all other information will be reported in ways which ensure that I cannot be identified. I am aware that if I have any comments or concerns regarding this study I may contact The Office of Human Research at the University of Waterloo: (519) 885-1211 (Susan Sykes at extension 6005), or contact either Richard Wells (extension 3069) or Bob Norman (extension 2205). With full knowledge of all foregoing, I agree, of my own free will, to participate as a subject in this study.

_________________________________________  ________________________________
(Print Name)                                      Signature of Subject

_________________________________________  ________________________________
Dated                                        Witnessed

I agree to allow video and/or photographs to be used in teaching or scientific presentations or publication of this work.

_________________________________________  ________________________________
(Print Name)                                      Signature of Subject

_________________________________________  ________________________________
Dated                                        Witnessed