Back Injuries in Heavy Industries, Part A: Defining Back Injury Outcomes for Research Purposes

Final Report to WorkSafeBC

April 2007

Mieke Koehoorn[1,2], Fan Xu[1], Judy Village[2], Catherine Trask[2], Christie Hurrell[3], Kay Teschke[1,2]

[1] Department of Health Care and Epidemiology, University of British Columbia, 5804 Fairview Avenue, Vancouver, BC, Canada
[2] School of Occupational and Environmental Hygiene, University of British Columbia, 2206 East Mall, Vancouver, BC, Canada
[3] Centre for Health and Environment Research, University of British Columbia, 2206 East Mall, Vancouver, BC, Canada

Table of Contents

Table and Figures

Main Messages

Occupational back injuries are very common in British Columbia, and they are also very costly due to lost workdays, compensation claims, and health care costs. Doing research on the causes and patterns of back injuries is challenging, in large part due to the fact that the causes and patterns of back injuries are not well understood.
Many research studies, and other stakeholders including compensation systems, have treated back injuries as an acute injury, brought on by a specific event. More recent research has suggested that we need to rethink our understanding of back injuries, and recognize them as a more chronic or episodic condition.

This study makes important contributions to the research literature around how to define and measure back injuries in occupational health studies.

- This study used medical services, hospitalizations and workers compensation data to study long term patterns of health care contacts (frequency of contacts, types of contacts, gaps between contacts) for back-related diagnoses among a cohort of 116,268 workers employed in heavy industry in British Columbia (forestry, wood and paper products, construction, transportation and warehousing). Health care contacts with back-related diagnoses were analyzed to identify patterns in the data over the long term based on the number and type of contacts, the consistency of contacts and the gaps between contacts;

- This study provides a definition of a new back injury, and identifies a number of distinct patterns of back injury among a group of workers employed in heavy industries. The results are of direct relevance to occupational health researchers interesting in investigating the etiology of back injury, and may also have relevance for clinicians providing care to workers with back injury interested in understanding the longer-term course of back morbidity and health care seeking patterns;

- This study provides methods by which to measure patterns of back injury for researchers designing etiologic and epidemiologic studies of back injury (and for clinicians interesting in understanding the longer term course of back morbidity):

    - In this heavy industry cohort, a back injury episode was defined by a minimum of two outpatient visits per year;
    - Separate episodes (incidence) were defined by a three year gap with no health care contacts; and
    - Individuals with chronic back injury (prevalence) were defined by a minimum of four health care contacts per year with no gaps in contacts from year to year.

Executive Summary

This study followed a large group of workers in five heavy industries from 1992 to 2001 in order to better understand how back injuries arise and change over time. By looking at the health care services used by workers, our research revealed distinct patterns of back injury. We also learned more about how to identify when a new back injury arises. Because it identifies unique patterns of back injury, our research will be useful for researchers studying the causes of occupational back injury and illness, and for clinicians who want to better understand health care seeking behaviours of those suffering from back injury.

The study followed a large group of workers employed in industries known for being at high risk for back injury: forestry, wood and wood products, transportation, warehousing, and construction. We looked at how the group of workers used health care services related to back injury diagnoses to paint a picture of how they experienced symptoms over time. The five different patterns of back injury that emerged from our study are:

- A group (22.9% of study population) with no back-related (diagnosed) health care contacts
- A group (26.4%) with a consistent high probability of back-related health care contacts throughout the 10-year study period
- The remaining groups had a changing pattern of back-related health care contacts over time (increasing and decreasing probabilities of experiencing back symptoms, ranging from 0% to 55% over time). We think that these three groups represent a similar pattern of episodic back injury.

Our research suggests that workers experience different patterns of back injury over time. The ten-year window of our study captured these different patterns by type and frequency of health care contact and informed the definition of chronic and new-onset back injury for use in future occupational research studies. We defined a back injury episode as at least two back injury-related outpatient visits per year. Separate episodes were defined by a three-year gap without any health care contacts. Workers who had at least four health care contacts per year for the entire study period were defined as experiencing chronic back injury.

The different groups identified by this research will be useful for other researchers engaged in studies of occupational back injury. The group that remained injury-free could be followed for future back injury, or could serve as a control group against which to compare other workers. Those experiencing changing patterns of back symptoms could serve as a population experiencing new back injuries in future studies, providing that they remain injury free for at least three years.

1. Context

1.1 The Study Components

This report describes the results of the study "*Back Injuries in Heavy Industries, Phase 1,* **Part A: Defining Back Injury Outcomes for Research Purposes.**" The primary purpose of this part of the study was to define new onset back injury episodes for use in occupational studies of the causes of back injury. This study has provided a rich dataset describing long term patterns of health care utilization in the five heavy industries studied:

- forestry;
- wood and wood products;
- transportation;
- warehousing; and
- construction.

To investigate pattern of back-related morbidity, we used a combination of health care databases including outpatient medical services (general practitioner, specialist and other health care provider visits), hospitalizations, and workers' compensation claim data. This report presents how we assembled the research database and how we defined health care contacts for back injury; how we analyzed multiple contacts with the health care system by type of contact to identify distinct groups of individuals with unique patterns of back injury; and how we used the findings to propose a definition of new onset back injury for use in future research studies.

The other component of this study "*Back Injuries in Heavy Industries, Phase 1,* **Part B, Risk Factor Exposure Assessment**" is reported separately. The two parts of this study comprise Phase 1 (methods development) of a research program aiming to understand the causes of back injury. We hope to use the results of this phase to design Phase 2, a study aimed at investigating the work-related cause of back injury.

1.2 Why Back Injuries are Important

Back injuries are among the most common workplace injuries in British Columbia. Between 1996 and 2005, there were 167,480 accepted compensation claims for back strain, representing ~25% of all claims, ~23% workdays lost, and ~20% of claims costs (1). There has been very little change in these proportions over time. More than a quarter of all back strain claims were from employees in five heavy industries: forestry, wood and paper products, construction, transportation, and warehousing. Using data for the period from 1996 to 2000, we calculated crude relative risks for back strain claims by industrial sector using the average risk over all 21 sectors as the baseline for comparison. The industries studied had above-average back claim risks (forestry RR=1.3; wood and paper products RR =1.3; transportation RR=2.5; warehousing RR=3.5; construction RR=1.7), making them an ideal focus for this study. These industries are also suitable to study because they include widely varying exposures to the factors believed to be the primary work-related causes of back injuries: materials handling, body postures, and whole body vibration.

1.3 Why Improved Definitions of Back Injury are Needed

Back injuries are the leading cause of activity limitations and health care utilization (2)and the most common reason for work disability and lost workdays in Canada(1). Despite considerable research efforts, reducing the incidence of back injury and the associated disability has remained challenging. One of the major reasons is that the understanding of the natural and clinical course of these injuries is poorly understood (3). Many forms of illness run an episodic course. Some of these, such as arthritis or asthma, are generally viewed as chronic conditions. Others such as back injuries have tended to be viewed as acute conditions. Many stakeholders such as disability compensation systems have traditionally framed back injuries as acute injuries requiring a local precipitating event at a point-in-time. Recent evidence suggests that we need to rethink this conceptual understanding and that back injuries may follow a more chronic or episodic course or trajectory. Hagberg's model (4) of musculoskeletal morbidity is consistent with descriptions of back injury as a continuum from pain and loss of mobility to vertebral degeneration. Similarly, Von Korff (5) describes the course of back injury as highly variable, occurring in transient, recurrent, and chronic phases. The National Research Council conceptual model (as summarized by Marras(6)) has at its basis a biological mechanism of biomechanical load-tolerance relationship. Injury to the musculoskeletal system occurs when a biomechanical load is imposed on tissue that exceeds tolerance levels or when tolerance has decreased due to repetitive exposures over time or as a result of aging. While there is increasing recognition of the chronic nature of musculoskeletal injuries, a lack of knowledge on the specifics around the clinical course of back injuries has made it difficult to effectively investigate new onset episodes, as is typically done in epidemiology to identify risk factors for illness incidence. A better understanding of how to characterize the episodic or chronic course of back injury could advance understanding of etiology, management and prevention (7). Understanding risk factors in the context of the natural history of back injuries is also required to target the timing and type of prevention strategies and clinical interventions to prevent further morbidity and limit on-going disability.

Several papers emphasize the challenges of defining back injury outcomes (6). One review of 81 studies (8) found that only 31 contained a definition of back outcomes and none provided any scientific evidence for the choice of definition parameters. Another review of outcome studies among primary care patients (7) found that only two studies described the episode frequency and recurrence of back injury over a long-term follow-up period. Finally, a review of 234 papers on recurrence of low back injury (9) identified 12 that focused directly on the issue of recurrence of low back symptoms. The authors concluded that definitional and follow-up differences contributed considerably to variations in estimates of prevalence and incidence for back outcomes.

The purpose of this study was to propose a definition of new onset back injury for use in occupational studies investigating the links between workplace risk factors and the etiology of back morbidity. We created a person-specific, longitudinal database (1992 to 2001) of health care contacts for a cohort of 116,26 workers employed in five heavy industries (forestry, wood and paper products, construction, transportation, and warehousing). Health care contacts with back-related diagnoses were analyzed using a semi-parametric mixture modeling procedure to investigate trajectories of morbidity over time and identify distinct patterns for identification of new onset morbidity.

2. Approach

2.1 Study Participants

The study sample included workers living in the Canadian province of British Columbia (BC) who were employed in one of the five target industries in 2001 (forestry, wood and paper products, warehousing, transportation, construction). The sample excluded workers whose employer did not pay their health premium in 2001. Although health care coverage is universal in BC the ability to identify workers by industry of employment is dependent upon an employer-paid health premium (versus self-paid or government paid, for example) recorded in the provincial health registration file {Koehoorn et al 2006}. Individuals with less than 10 years of continuous follow-up between 1992 and 2001 were also excluded from the analysis to ensure capture of longitudinal patterns of back morbidity for all subjects.

2.2 Study Methods

2.2.1 Data Sources

Health data was available through the British Columbia Linked Health Database (BCLHD). The BCLHD is an extensive data resource for applied health services and population health research {Chamberlayne et al 1998; British Columbia Ministry of Health, 1998}. It includes longitudinal, person-specific, health data on the province's four million residents, covering the study follow-up period. For the purposes of this study, the data available included the universal health insurance registration file of BC residents, workers' compensation claims, hospital discharge records (including day procedures/surgeries), and medical services outpatient visits to general practitioners, specialists, and other practitioners (e.g. chiropractors and physiotherapists). All of the health records included a date of service and diagnosis codes (International Classification of Diseases 9th Revision (ICD9) (10)). The data for the study sample were merged using common personal identifiers across the four different data sources with a 97% success rate. The merged data set was provided to the research team with all unique identifiers removed. The project was approved by the University of British Columbia Behavioural Research Ethics Board.

2.2.2 Outcome Definition for Analysis of Incidence, Prevalence and Back Injury Trajectories

The outcome of interest was a health contact (dichotomous yes or no) with a back-related ICD9 diagnosis[1]. Health contacts were defined as a unique short-term (time loss) or long-term (permanent disability) compensation claim, or a hospitalization, or an outpatient visit to a general practitioner or a specialist. An outpatient visit was defined by a unique combination of the service date and practitioner code. For example, an individual with multiple services on the same day provided by a single practitioner was counted as one visit. Hospitalizations were limited to those where the back-related ICD9 diagnosis was the primary or most responsible diagnosis for their admission and length of stay respectively (out of a possible 16 diagnostic codes recorded in the hospitalization record).

Only one diagnosis code was recorded per outpatient visit or workers' compensation claim and was assumed to be the primary reason for care or for compensation.

For the purposes of calculating incidence and prevalence, the definition was further restricted to 2 outpatient visits in a year in order to count as a case within that year. Individuals had to be free of back injury health care contacts for a minimum of three years across all data sources and were counted as an incident case in the year they presented with 2 outpatient visits, a workers' compensation claim or a hospitalization, which ever occurred first. Prevalence was calculated as the cumulative 10 year prevalence during the study period (if an individual ever met the case definition) as well as the yearly prevalence (if they met the case definition in that year). Prevalence and incidence estimates were further stratified by industry and by back injury location (cervical, thoracic, lumbar or unspecified).

Diagnoses for acute, traumatic injuries such as fractures to the back were excluded from the analyses as not relevant to understanding the longer term patterns of health care contacts associated with a chronic and recurrent model of musculoskeletal morbidity of interest in this study. Relevant diagnostic categories included in the study represented degeneration or displacement of intervertebral discs or intervertebral disc disorders; spinal stenosis, neuritis or radiculitis; cervicalgia, cervicocranial syndrome, lumbago, sciatia, backache, strains and sprains, and other unspecified symptoms of the back. The back injury outcome was further characterized by anatomical location (cervical, thoracic, lumbar or unspecified[1]) using the ICD9 codes.

As a surrogate of severity of back morbidity, a combination of a workers' compensation claim and a hospitalization in a 12 month period was weighted as more severe (weight=4) in the analysis compared to a hospitalization only (weight=3), a workers' compensation claim only (weight=2), an outpatient visit only (weight=1) or no contacts (weight=0). Individuals were coded according to the above severities for each 12-month window from the start of follow-up in 1992. For example, Subject A with zero back-related health care contacts in 1992 through to 1994 was coded '0' for each of these years, then coded '1' for outpatient visits in both 1995 and 1996, coded '2' for a workers' compensation claim in 1997, and finally coded '1' each year through to the end of follow-up in 2001 for outpatient visits in each of those years.

2.2.3 Trajectory Analysis

A group-based method described by Nagin and colleagues (11, 12) was used to identify unique groups or trajectories of back injury morbidity (based on severity-weighted health care contacts as described above) among the study sample. Trajectory analysis is designed to model individual-level heterogeneity in data over time, as opposed to more traditional regression analyses that model only

[1] Cervical: ICD9=722.0, 722.4, 722.71, 722.81, 722.91, 723, 723.01, 723.02, 723.1, 723.11, 723.12, 723.13, 723.14, 723.2, 723.21, 723.27, 723.3, 723.33, 723.4, 723.45, 723.5, 723.6, 723.7, 723.71, 723.72, 723.8, 723.9, 723.91, 723.96, 739.1, 739.11, 739.12, 739.13, 739.17, 739.18, 847.0, 847.01, 847.07; Thoracic: ICD9=722.11, 722.31, 722.51, 722.72, 722.82, 722.92, 724.01, 724.1, 739.2, 739.21, 739.23, 739.24, 739.25, 739.27, 739.28, 739.29, 847.1; Lumbar: ICD9=722.1, 722.32, 722.52, 722.73, 722.83, 722.93, 724.02, 724.2, 724.21, 724.24, 724.3, 724.6, 724.7, 724.71, 724.72, 724.79, 739.3, 739.31, 739.32, 739.36, 739.38, 739.4, 739.41, 739.43, 846, 846.03, 846.1, 846.11, 846.13, 846.2, 846.3, 846.4, 846.5, 846.6, 846.7, 846.8, 846.9, 847.2, 847.21, 847.3, 847.4, 847.41); and Unspecified: ICD9=722, 722.1, 722.2, 722.3, 722.39, 722.5, 722.58, 722.6, 722.7, 722.8, 722.80, 722.9, 724, 724.06, 724.08, 724.09, 724.4, 724.45, 724.5, 724.51, 724.52, 724.53, 724.54, 724.58, 724.8, 724.9, 724.92, 724.99, 847, 847.5, 847.6, 847.61, 847.7, 847.8, 847.83, 847.84, 847.87, 847.9, 847.91.

one mean within a sample. Rather than assume that the distribution of trajectories varies continuously across individuals, it assumes that there may be clusters or groupings of health care utilization patterns that reflect distinct injury progression patterns and perhaps distinct etiologies.

The group trajectory estimation was completed using the SAS procedure PROC TRAJ (13). The analysis proceeded in two stages. First, distinctive trajectories of back-related health care contacts were identified using a semi-parametric, mixture model. The trajectory analysis requires the researcher to make some assumptions about the distribution of trajectories in the sample. A key step in this stage of model estimation was a) the selection of the number of trajectory groups and b) the shapes of the trajectories over time (linear, cubic, quadratic). With limited evidence in the literature on the long term course of back injuries, models with two to five groups allowing for linear, cubic or quadratic shapes were estimated in this study. Model selection was based on change in the Bayesian Information Criterion (BIC)(13). The difference in the BIC between models is a measure of the evidence for a more complex model (e.g. larger number of groups or higher order equation, or more covariates) with Jones recommending a two to six point change in the log BIC as evidence of a better model.

For the second phase of the analysis, the patterns of health care contacts within each of the identified trajectory groups were described over the long term, including the type of health care contacts, the frequency of contacts, and the gaps in health care contacts. Based on these results, a definition of a new onset back injury episode using administrative health data is proposed for use in future research study of working populations. All analyses were completed in SAS version 9.1(14).

3. Results

3.1 Study Participants

A total of 137,698 individuals were identified in the provincial health registration file as living in British Columbia and working in one of the five target industries in 2001. Of these workers, 21,430 (15.6%) were excluded because they had less than 10 years of continuous follow-up, leaving a total study sample of 116,268 workers. Excluded workers were younger than the overall sample by an average of seven years and were overrepresented in the construction and transportation industries.

At the time of cohort enumeration in 2001, the analytic sample was predominantly male (81.7%) with a mean age of 42.8 years (sd 11.1) (Table 1). The largest group of workers was employed in the wood and paper products industry and the smallest group in the warehousing industry. Given the requirement for continuous enrolment the gender distribution remained the same during the retrospective follow-up study period and the cohort was an average of 10 years younger in 1992.

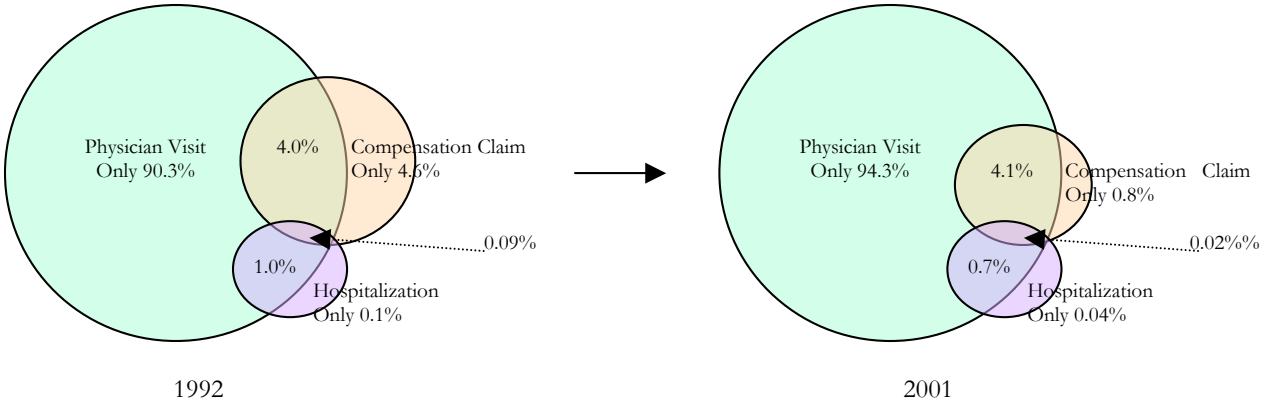
Table 1: Description of Study Sample - Workers Employed in Heavy Industries in 2001

	Excluded Workers *n=21,430*	*Included Workers* *n=116,268*	*Subset of Included Workers with Back Injuries* *n=86,239*
Mean Age in 2001	35.6 (sd 9.0)	42.8 (sd 11.1)	42.8 (sd 10.9)
% Males	79.3%	81.7%	80.6%
Industry in 2001			
Wood Paper Products	27.1%	34.4%	33.8%
Transportation	34.0%	29.7%	30.6%
Construction	26.2%	17.0%	17.0%
Forestry	10.1%	16.2%	15.8%
Warehousing	2.7%	2.7%	2.8%

3.2 Description of Back Health Care Contacts

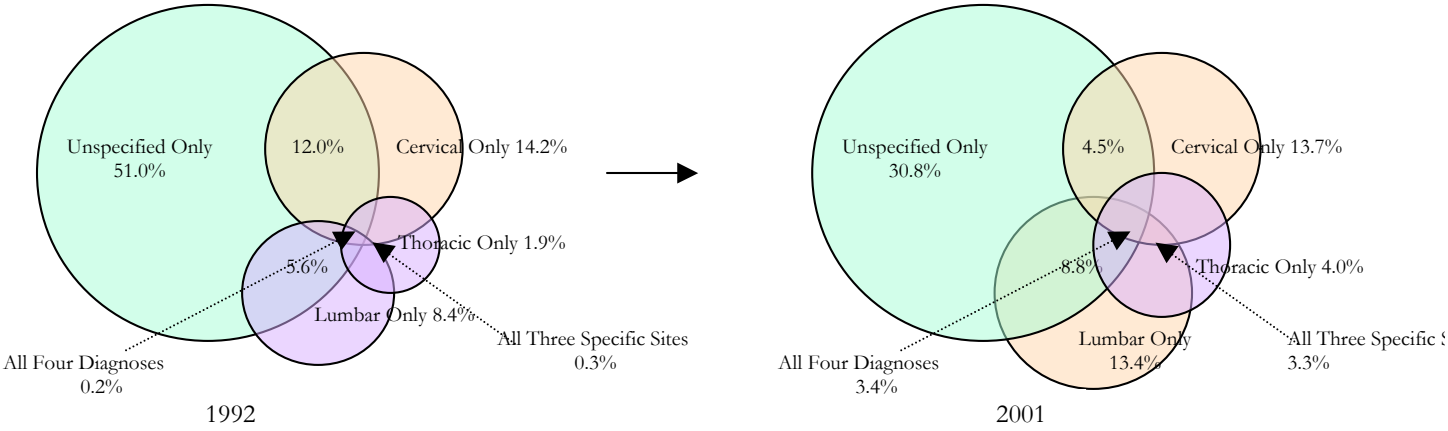
In the first year of follow-up, 24.5% of the study sample had a back injury as defined by a diagnosed back-related health care contact or workers' compensation claim. This figure rose steadily to 29.5% by the last year of follow-up. During the 10 year follow-up window, 74.2% of the study sample (n=86,239) had had at least one diagnosed back-related contact with the health care or compensation system. Individuals with a back injury did not differ significantly from the overall study sample in terms of age, gender or industry distribution (Table 1). The majority of back-related health care contacts were outpatient physician visits (95.4% of all contacts in 1992 rising to 99.2% in 2001) (Figure 1). The annual proportion of back-related contacts defined by a workers' compensation claim dropped from 8.6% to 4.9% over the follow-up period and those defined by a hospitalization fell from 1.2% to 0.8%.

Figure 1a: Type of Back-Related Health Care Contacts among Study Sample from 1992 to 2001



The majority of health care contacts were for unspecified back diagnoses in 1992 (51.0% unspecified only and an additional 21.6% in combination with visits for other types of diagnoses (Figure 1b)). Visits were more frequently specified by the end of follow-up across cervical (37.8% alone or in combination), lumbar (37.9%), thoracic (23.6%), and unspecified back diagnoses (55.6%). The change over time was largely attributable to change in diagnoses for outpatient visits as more than half of hospitalizations were consistently coded as unspecified back diagnoses over time (62.9% in 1992 and 55.8% in 2001) as were workers' compensation claims for lumbar diagnoses (52.3% in 1992 and 52.2% in 2001).

Figure 1b: Type of Back-Related Diagnoses for Health Care Contacts among Study Sample from 1992 to 2001



3.3 Prevalence and Incidence Estimates

The overall cumulative prevalence of back injury (as defined by the presence of at least one compensation claim, one hospitalization or 2 outpatient visits within 12 months) among the study population over the follow-up period was 63.7%. For type of back injury diagnoses, the cumulative prevalence was highest for unspecified back injuries at 45.1% (yearly prevalence ranged from 13.2% in 1992 to 10.2% in 2001) followed by of lumbar injuries at 33.0% (3.7% to 8.8%), cervical injuries at 32.8% (5.9% to 8.4%) and then thoracic injuries at 19.4% (0.9% to 5.3%). The yearly prevalence of back injury rose from 19.8% in 1992 to 23.1% in 2001. Overall and by site of injury, workers in the forestry industry tended to have the lower prevalence estimates of back injury while workers in the transportation industry tended to have the higher estimates.

The yearly incidence of back injury (for those who met the case definition but were injury free for at least three years prior) was fairly consistent but rose slightly over time at approximately 5.7% to 5.9% of the study population from 1995 to 2001. This slight increase in injuries was evidence for all types of back injury diagnoses/injury sites. By industry the increase in the incidence of back injury was most noticeable among workers in the construction industry (5.4% to 6.3% over time) and the forestry industry (5.4% to 6.1%). Incidence was fairly stable for workers in the transportation (5.9 to 6.1%) and wood/paper products industry (5.6% to 5.9%) and dropped slightly for workers in the warehousing industry (5.9% to 5.2%).

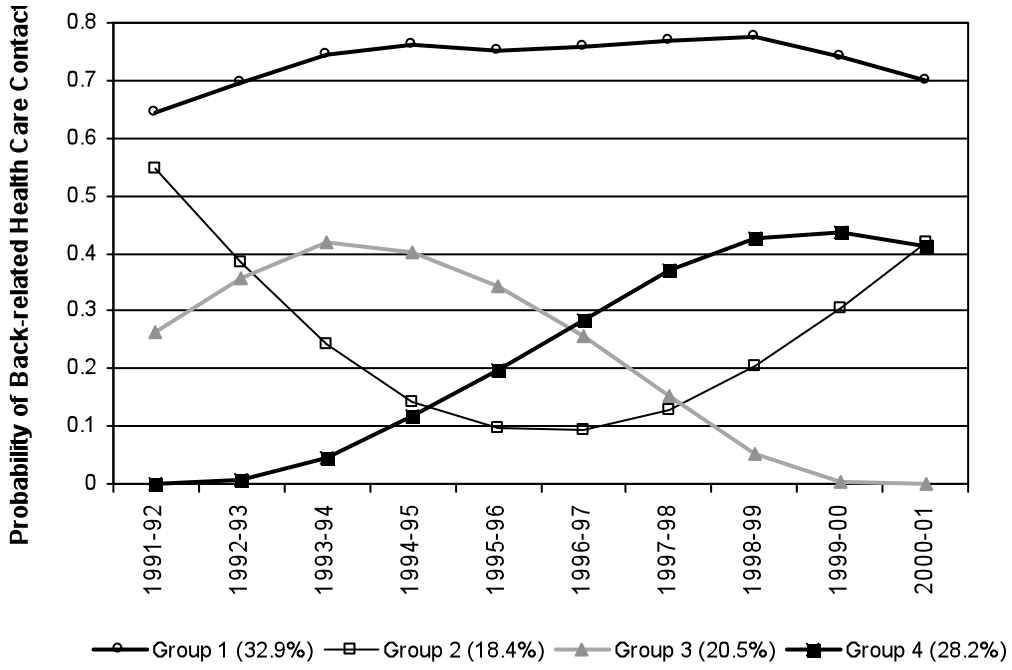
3.4 Trajectory Results

Four trajectories or distinct patterns of back injury (data not shown), as defined by contacts with the health care (outpatient and inpatient visits) or workers' compensation system, were identified as the best fit for the study sample. The first was composed of individuals with a low probability (<0.001) of ever having a diagnoses back-related health care contact over the entire follow-up period and included 22.9% of the study sample. The second group (26.4% of the sample) was composed of individuals with a consistently high probability (>0.6) of having a diagnoses back-related health care contact every year of the follow-up period. The two remaining groups, 31.4% and 19.3% of the cohort respectively, followed episodic patterns of increasing (0.10 rising to 0.40) and decreasing probabilities (0.30 to 0.01) of back-related health care contacts. Individuals in the low probability trajectory group were on average younger compared to the other groups (e.g. mean age of 42.5 years versus to 44.6 years for the high probability group), were less likely to be female (e.g. 16.4% versus 24.2%) and were less likely to be in the construction industry (27.9% versus to 35.6%) but more likely to be in forestry (16.9% versus 14.5%) or wood and paper products (35.7% versus 29.7%).

The trajectory analyses was re-run for the subset of the study sample with at least one back-related health care contact during the study follow-up period (n=86,239) to help confirm patterns of back morbidity defined by health care contacts. Four trajectories of back-related health care utilization were identified as the best fit of the data among this subset (Figure 2). There remained a group with a high probability (~>0.70) of back-related health care contacts in each year of follow-up representing 32.9% of the subset. The three other groups had episodic trajectories, including one group representing 18.4% of the subset that started with a high probability of a back-related contact (0.55), dropped to a low probability and then started to rise again toward the end of follow-up

(0.42). A second group including 20.5% of the subset started with a lower probability (0.26), that rose (0.42) and then fell again (0.01) during follow-up. The third group including 28.2% of the subset started with a zero probability that steadily increased over the follow-up period (0.43) but began to plateau or drop in the final years of follow-up (0.40).

Figure 2: Trajectories of Back Injury among Workers in Heavy Industry (subset with at least one diagnosed back-related health care contact over a 10 year follow-up period (n=86.239)



3.4.1 Characteristics of Back Injury Subset, by Trajectory Group

Women represented 18.3% of the study sample, 19.4% of the subset with at least one back-related health care contact, and 21.9% of those in the trajectory with a high probability of a back-related health care contact. Workers in the transportation industry represented 29.7% of the study sample, 30.6% of the back morbidity subset, and a slightly higher proportion of those in the high probability trajectory (33.9%).

In terms of types of health care contacts, Group 1 (high probability group) was defined by an average of four and five outpatient visits per year for back-related diagnoses over the entire follow-up period. Group 2 (episodic) was defined by an average of two out-patient contacts for back-related diagnoses per year during the first two and last two years of follow-up (periods with a high probability of a health care contact). The intervening years were defined on average by less than one contact per year (0.2 to 0.4). Group 3 (declining episode) was defined by an average of two outpatient contacts per year during the first five years of follow-up declining to less than one contact per year on average and zero visits for the final three years of follow-up. Group 4 (increasing episode) was defined by an average of zero contacts per year for the first three years of follow-up,

gradually increasing to an average of two outpatient contacts per year during the final five years of follow-up. The majority of all back-related hospitalizations (69.2%) and lost-time compensation claims (50.9%) occurred in the chronic back trajectory group (Group1). In summary, an episode of back injury was defined by a minimum of two out-patient visits per year and a minimum three-year period with no health care contacts between distinct episodes of back injury. Chronic back injury was defined by a minimum of four visits to a health care practitioner per year and/or a workers' compensation claim and/or a hospitalization, with no gaps in health care contacts from year to year.

3.4.2 Sensitivity of Trajectories to Stratification by Industry and Back Diagnoses Location

The trajectory analysis was rerun on the injured subset, stratified by industry (construction warehousing, forestry, wood and paper products, and transportation) and by type of back diagnoses (cervical, thoracic, lumbar and unspecified). In all cases, the four group trajectory was the best fit to the data with a chronic group and three episodic groups (results not shown). The analyses were also rerun with the study outcome unweighted by type of health care contact (0/1 only). Again, the four group trajectory (one chronic and three episodic groups) remained the best fit to the data (results not shown).

Dual trajectory analysis (11), used to analyze the connections between distinct but related outcomes, was applied to the data to investigate the associations between morbidity defined by different types of back diagnoses (cervical, lumbar, thoracic, unspecified). In other words, is the probability of belonging to an episodic cervical group distinct or conditional on membership in an episodic lumbar group? Using lumbar and unspecified diagnoses for example, both diagnoses on their own indicated a four group trajectory as noted above. However, Figure 2a and 2b presents the linkage between the lumbar and unspecified diagnoses. The first series (Figure 2a) is the probability of membership in each of the unspecified trajectory groups, conditional upon membership in each of the lumbar trajectory groups. These probabilities can be interpreted as the probability of transitioning from each lumbar trajectory to each unspecified trajectory. No matter how the comparison was analyzed (e.g. lumbar versus cervical, cervical versus thoracic, lumbar versus unspecified), the results show a relationship between the trajectories for the two outcomes under investigation. Figure 2a shows that those in an unspecified trajectory (chronic, episodic) were more likely than not (>0.51) to be in the same lumbar trajectory (chronic and episodic respectively), but those in an episodic group were not more likely to be in the chronic group or vice versa. Figure 2b shows the same (reverse) relationship but membership in some of the episodic lumbar groups was strongly related to membership in the same episodic unspecified group (>0.74). In other words transition from an unspecified trajectory to a lumbar trajectory was more likely than transition from a lumbar trajectory to an unspecified trajectory, especially for episodic groups. Notwithstanding these overall tendencies, the dual trajectory results also indicate that membership in one type of back trajectory (unspecified) is not a certain predictor of another type of trajectory (lumbar).

Figure 2a: Relationship of Lumbar Back Diagnoses with Unspecified Back Diagnoses

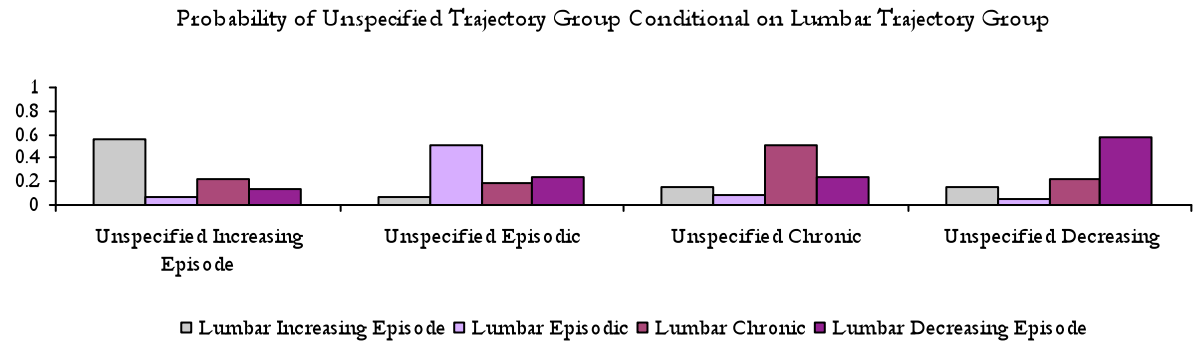
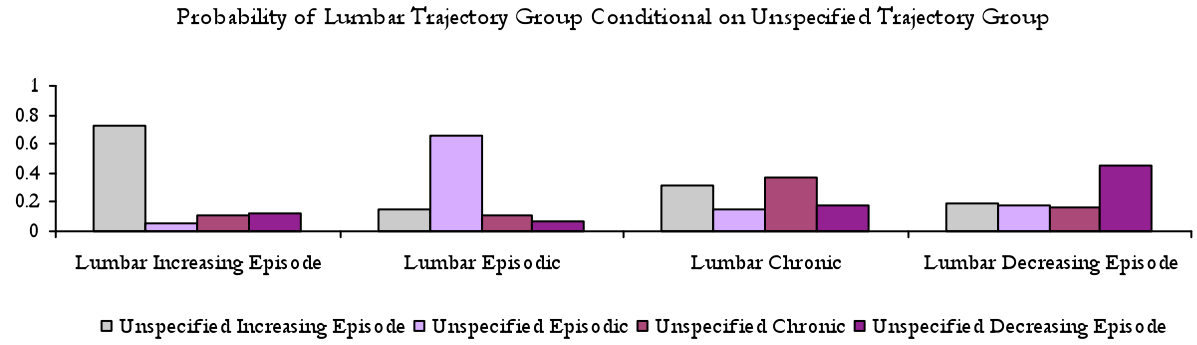


Figure 2b: Relationship of Unspecified Back Diagnoses with Lumbar Back Diagnoses



4. Discussion and Implications

4.1 Summary of Findings

The prevalence of back injuries has been investigated in numerous cross-sectional studies, but there are very few studies that describe the pattern or trajectory of back morbidity (as measured by diagnosed health care contacts) over a long term follow-up period. This study provided a unique window on long-term health care utilization for multiple types of contact (outpatient offices, hospitals, workers' compensation systems) using trajectory analyses. While several studies have investigated recurrences of existing back injuries, we sought to define a new episode of back injury, based on a chronic and recurrent model of morbidity, in a working sample known to be a high risk for work-related back injury. We identified distinct trajectories in the study sample – a group with no back-related health care contacts over the long term, a group with a consistent (chronic) high probability of health care contacts over the long term, and episodic groups defined by periods of both high and low probability of a back-related health care contact over a long term follow-up window. Among workers with at least one back-related health care contact over the 10 year follow-up window, the chronic (one group) and episodic trajectories (three groups) remained. We postulate that the episodic groups (those with increasing and decreasing probability of health care contacts during the 10-years follow-up period) are all representative of the same temporal pattern just observed at different starting points for individuals in the cohort.

The results of this study provide useful information for designing etiologic studies of back injury for occupational health researchers which require the identification of new episodes of back morbidity and not recurrence within an episode (15). In this heavy industry cohort, 22.9% of the study sample (a cohort defined by high risk industries) had no history of back morbidity and could be followed for future injury incidence in cohort studies, or could serve as a control group in case-control designs. It is important to note that we did not have information on occupation within industry and this low probability group may represent individuals with less physically demanding jobs or high risk jobs for back injury, such as administrative or management jobs in heavy industry. The episodic morbidity group could serve as a source of incident cases in either cohort or case-control designs, as long as they had been injury free for at least three years. The chronic group (26.4% of the sample) had ongoing prevalent back morbidity and would be less useful for etiological studies.

4.2 Consistency with Previous Studies

The 10-year cumulative back injury prevalence of 63.7% in our study sample is consistent with previous studies of reported life-time prevalence in the general population (16, 17) although perhaps a bit higher than that reported for working populations given the longer follow-up period and the high risk industries. The annual prevalence of 19.8% to 23.1% is consistent with some studies (18) but lower than that reported for some working populations (19) including heavy industry (20). This may be as a result of relying on identification of diagnosed back injury in this working sample.

A total of 26.4% of our overall study sample were defined by a chronic back injury trajectory. This is higher compared to other studies with a definition of chronic back morbidity (21) including working

populations (22) although previous studies were based on self-reported measures over a shorter follow-up window. Other studies indicate that up to 70 to 80% of individuals with back injuries continue to have symptoms one year after the initial onset (5). To our knowledge, no prior studies have followed health care utilization among workers for such an extended period, and therefore there are no prior reports of such persistence.

We found that 50.7% of the overall study sample experienced an episodic trajectory of back injury (which appears to include a combination of recurrences within an episode, a long period of relief from injury, then the start of a new episode). This is consistent with previous studies reporting 50-70% of individuals with back morbidity having a recurrence (23-26), although these rates are greatly dependent upon the definition of recurrence and the time window of follow-up(9, 27). Others have reported a recurrence rate among workers of 33.9% using recurrent health care (28) and 42% using self-reported symptoms (29).

A decrease in the percentage of the study sample with hospitalizations and compensation claims for back related diagnoses over time is consistent with observed trends in North America for both types of health care contacts (1, 30, 31). A decrease or plateau in compensation claims appears to be consistent with changes in injury trends (or changes in the nature of work affecting injury trends) and not due to changes in compensation policies (31) while a reduction in hospitalizations appears to be consistent with a change in clinical practices away from admissions for ineffective treatments for back injury such as bed rest and traction (30).

4.3 Sensitivity Analyses

Analyses run by diagnoses type found the same four-group best fit to the data and the dual trajectory analyses indicated that those with one type of diagnoses were more likely than not to also have another type of diagnoses for a similar trajectory (be it chronic or episodic). In other words diagnoses type was not particularly helpful in identifying distinct groups. However, the strongest conditional probabilities were found for transition from unspecified diagnosis groups to specified (lumbar, thoracic or cervical) groups. This may indicate that individuals who first present with back symptoms are given an unspecified diagnosis but with increasing contact with the health care system (and perhaps more medical/diagnostic procedures) are eventually given a more specified diagnoses.

4.4 Trajectory Analyses

The trajectory procedure was originally developed for estimating developmental trajectories among children and has been used widely in the psychology and sociology literature (e.g. 32, 33). Technically, the modeling procedure uses a mixture of probability distributions. In other words, it assumes that, rather than being continuously distributed in the population, trends in the course of back injury for example differ for different subgroups in a population. Trajectory analysis does not provide any individual-level information on the pattern of change over time; subjects are grouped and every subject in the group contributes to the average pattern for that trajectory. While many outcomes that we study, including back injury, may not show clear cut points differentiating injury from no injury, the trajectory analyses facilitates the identification and definition of distinct groups and parameters for future research investigating risk factors associated with the onset of injury at the

individual level. The group-based approach is ideally suited for testing whether there are distinctive groups and patterns in the data provided the assumption that different patterns exist is accepted a priori.

Lost in this type of analysis are the unique patterns of individual back injury trajectories. However, even if the population is made up of a series of unique individual-level trajectories, the trajectory procedure applies statistical methods to model their similarities and differences to identify distinct groups with similar temporal patterns of injury. Thus it detects order between individual patterns over time. It is also important to note that trajectory analysis is a statistical device for approximating population differences in injury trajectories. Nagin, the principle architect of the method, warned about a popular misconception that individuals actually belong to a trajectory group (34). Instead, trajectory analysis is a statistical tool summarizing more complex behaviours of a set of individuals. The data summary captures the average behavioural trend of a collection of individuals and is intended to reflect long-term average patterns not short-term individual variability about the pattern.

4.5 Study Sample

Industry of employment in the medical services registration is based on employer-paid health premium information. As a result there may be some misclassification of workers by industry given reliance on a yearly snapshot for the registration file and employer changes within a year. In order to investigate this, a sub-analysis was conducted to compare the industry of employment code in the 2001 registration file with the industry of employment code in the workers' compensation records for those individuals who had an accepted claim in 2001 and would appear in both databases. Of the 8,721 individuals with a work-related compensation claim in 2001, there was 94.0% agreement between the two sources of industry information.

Industry coding is only available for approximately half of the workforce in British Columbia and under-represents workers who are self-employed or work for small employers (i.e. that do not tend to have employer-paid health premiums). Using data from the 2001 Labour Force Survey (BC Stats, 2006), we estimate that we were able to identify 50.7% of the workers in the five target industries. The distribution of workers across the five industries in our sample differed from the distribution in the Labour Force Survey and may be a reflection of differences in employer-paid health premium coverage or industry mobility. Workers with less than 10 year of follow-up, who we excluded from the study, tended to be in the construction and transportation industries and as a result the distribution of workers in these industries across the entire study sample was lower compared to the LFS estimates (e.g. 17.0% of our study population was in construction compared to 28.1% in the LFS; 29.7% in transportation in the study sample compared to 35.2% in the LFS).

4.5 Conclusions

Most studies of back injuries and related morbidity are based on self-reports (25, 35, 36) and many occupational studies are based on workers' compensation claims (28), although some researchers define cases based on visiting a health care provider (26, 37) or a combination of data sources (38). Using a combination of data sources may be important for chronic and episodic conditions, especially for work-related conditions.

Dembe and colleagues (39) estimated that 17.8% of health care visits for work-related conditions were paid by sources other than workers' compensation insurance. This is consistent with Canadian (40) and American studies (41) that have shown an under-reporting of workplace conditions to workers' compensation systems. In the present study, given the low percentage of the population with a claim and the high percentage of the population with outpatient visits to health care professionals for back morbidity, the reliance on claim data as the outcome of interest in occupational studies may miss a significant portion of participants with back morbidity as well as early indicators of the onset of morbidity prior to work disability. Although we cannot conclude that all of the contacts with health professionals were for *work-related* back morbidity, research by Hertzman and colleagues (42) showed, in a longitudinal, population-based workforce study in British Columbia, an increase in general practitioner visits leading up to a workers' compensation claim, a peak during the claim year and then a decrease, though not to former levels among injured workers. It is hypothesized that observed increases in health care utilization during and after an injury are work-related, even though not reimbursed by the workers' compensation system but rather through the publicly funded health care system. This may be especially true for chronic and episodic conditions such as musculoskeletal injuries where it might be easier to seek care for symptoms through the public health care system without having to 'prove' work-relatedness.

Application of case definitions in epidemiological studies to identify individuals with no back injury/morbidity, chronic back injury and episodic back injury requires access to a comprehensive set of health data that may not be available to all researchers in all jurisdictions. Access to outpatient medical services data may be sufficient to distinguish groups given this was the predominant source of health care contacts (e.g. over 99% of those with at least one contact saw a health practitioner for a back-related diagnoses 2001) and the number of visits per year was a key component distinguishing trajectory patterns (although knowledge of hospitalizations and compensation claims would further define the chronic trajectory group). Access to pharmaceutical records may add to future work on case definitions but the type of drugs typically prescribed for back injury are also typically prescribed for numerous other types of pain and may not be a sensitive measure of back-related health care contacts.

Defining a new episode of back injury requires specification of the between-episode gap (three years proposed based on the findings in this study), and the ability to identify a new episode will be highly dependent on the length of follow-up and access to a combination of health-related data sources (43). The results of our study have implications for researchers who might be considering embarking on epidemiological studies to investigate the etiology of back injury. We used a variety of health database to gather a large amount of data on health care contacts over a longitudinal follow-up period. Based on this health data, we are able to propose some definitions of back injury outcomes for use in future studies. In this heavy industry cohort, those with no history of back injury could be followed for future incidence in cohort studies, or could serve as a control group in case-control designs. The episodic injury group could serve as a source of incident cases in either cohort or case-control designs, as long as they had been injury free for at least three years.

5. Dissemination Plans

The knowledge exchange portion of this study has been performed in collaboration with the Centre for Health and Environment Research (CHER). As an organization, CHER has a mandate of making relevant research information available and accessible for practice, planning, and policy-making. Knowledge transfer activities for Part A will target researchers in particular as well as several stakeholder groups interested in identifying back injury outcomes for measuring incidence and prevalence of back injury or understanding the clinical course of back injury among injured workers.

Lay audiences

1) This report, in full, will be sent to WorkSafeBC and posted on the project website. The existing back study website was prepared in collaboration with CHER and has already been promoted to research and stakeholder groups. To date, this website has had 50,000 hits and an average of ten visitors per day.
2) Presentations will be made upon request to research seminars (School of Occupational and Environmental Hygiene, Institute for Work and Health, Workers' Compensation Research Group) as well as professional organizations who could make use of the findings on the course of back injury among workers in heavy industry for clinical or compensation program;

Researchers

3) Summaries will be prepared in collaboration with CHER and targeted to occupational health researchers, and to industry stakeholders (e.g. industrial workplace health and safety employees/joint health and safety committee members) interested in undertaking studies of the risk factors associated with back injuries.

Scientific Audiences

4) International and national conference presentations, including:
    - Koehoorn M, Teschke K, Village J, Trask C, Xu F. Back Injury Trajectories among a Cohort of Heavy Industry Workers in British Columbia (submitted). EPICOH2007: 19th International Conference on Epidemiology in Occupational Health. Banff, Canada: October 9-12, 2007.
5) Publications in peer-reviewed, indexed scientific journals, including media/press releases to a broader audience, including:
    - Koehoorn M et al. Back Injury Trajectories among a Cohort of Heavy Industry Workers in British Columbia. For submission to Spine May 2007;

6. Further Research

This study was the first phase (methods development) of a research program to study the causes of back injuries in heavy industries and to test ways to reduce them. Phase I (Part A and Part B) addressed two persistent methodological problems in back injury epidemiology, the difficulty of case definition and ascertainment, and the difficulty of measuring exposures for large scale epidemiological studies. To do so, this study examined the health care history and descriptive epidemiology of back injuries within the health care and compensation systems; and measured exposures to specified work site risk factors (materials handling, trunk postures and whole body vibration), with the aim of creating predictive models of exposure. In **Phase 1** we established case definitions based on administrative health and compensation records, and exposure assessment methods for measuring physical risk factors across a variety of occupations and work environments. Phase 1 provided invaluable data for the research team to plan Phases 2 and 3 (and provide stand-alone value for employers and employees of the target industries with regards to exposure assessment techniques, and for health care and compensation providers with regards to a better understanding of the course of back injuries for effective management and disability prevention). Based on the findings from Phase I, **Phase 2** (the subject of a future proposal), will investigate the relative importance of the many postulated risk factors and their interactions in the etiology and progression of new onset and chronic back injuries in heavy industry. This data and data from Phase 1 will be used to design control measures. **Phase 3** (also the subject of a future proposal) will be a randomized workplace trial of the effectiveness of various control measures to reduce the risk of work-related back injuries. Each of the first two phases is expected to contribute to the design of the subsequent phases, but will also contribute important independent scientific results.

7. References

1. WorkSafeBC. Statistics 2005: From awareness to action. Richmond, British Columbia: WorkSafeBC; 2006.
2. Health Canada. Economic burden of illness in Canada, 1998. Ottawa, Ontario: Her Majesty the Queen in Right of Canada, Government Services Canada; 2001. Report No.: H21-136/1998E.
3. Cassidy JD, Cote P, Carroll LJ, Kristman V. Incidence and course of low back pain episodes in the general population. Spine. 2005 Dec 15;30(24):2817-23.
4. Hagberg M, Christiani D, Courtney TK, Halperin W, Leamon TB, Smith TJ. Conceptual and definitional issues in occupational injury epidemiology. Am J Ind Med. 1997 Aug;32(2):106-15.
5. Von Korff M. Studying the natural history of back pain. Spine. 1994 Sep 15;19(18 Suppl):2041S-6S.
6. Marras WS. State-of-the-art research perspectives on musculoskeletal disorder causation and control: The need for an intergraded understanding of risk. J Electromyogr Kinesiol. 2004 Feb;14(1):1-5.
7. Von Korff M, Saunders K. The course of back pain in primary care. Spine. 1996 discussion 2838-9; Dec 15;21(24):2833-7.
8. de Vet HC, Heymans MW, Dunn KM, Pope DP, van der Beek AJ, Macfarlane GJ, et al. Episodes of low back pain: A proposal for uniform definitions to be used in research. Spine. 2002 Nov 1;27(21):2409-16.
9. Wasiak R, Pransky GS, Webster BS. Methodological challenges in studying recurrence of low back pain. J Occup Rehabil. 2003 Mar;13(1):21-31.
10. Practice Management Information Corp (PMIC). International classification of diseases 9th revision: Clinical modification sixth edition. Los Angeles, California: 2003.
11. Nagin DS, Tremblay RE. Analyzing developmental trajectories of distinct but related behaviors: A group-based method. Psychol Methods. 2001 Mar;6(1):18-34.
12. Nagin DS. Analyzing developmental trajectories: A semi-parametric, group-based approach. Psychol Methods. 1999;4:139-77.
13. Jones B, Nagin DS, Roeder K. A SAS procedure based on mixture methods for estimating developmental trajectories. Sociol Method Res. 2001;29:374-93.
14. Statistics for the Applied Sciences (SAS) Institute Inc. The SAS system. 2002-2003;9.1.
15. Andersson GB. Epidemiological features of chronic low-back pain. Lancet. 1999 Aug 14;354(9178):581-5.
16. Leboeuf-Yde C, Lauritsen JM. The prevalence of low back pain in the literature. A structured review of 26 Nordic studies from 1954 to 1993. Spine. 1995 Oct 1;20(19):2112-8.
17. Cassidy JD, Carroll LJ, Cote P. The Saskatchewan health and back pain survey. the prevalence of low back pain and related disability in Saskatchewan adults. Spine. 1998 discussion 1867; Sep 1;23(17):1860-6.
18. Andersson GB. Epidemiology of low back pain. Acta Orthop Scand Suppl. 1998 Jun;281(Supplementum. 281):28-31.
19. IJzelenberg W, Burdorf A. Risk factors for musculoskeletal symptoms and ensuing health care use and sick leave. Spine. 2005 Jul 1;30(13):1550-6.
20. Hussain T. Musculoskeletal symptoms among truck assembly workers. Occup Med (Oxf). 2004 Dec;54(8):506-12.
21. Leclerc A, Chastang JF, Ozguler A, Ravaud JF. Chronic back problems among persons 30 to 64 years old in france. Spine. 2006 Feb 15;31(4):479-84.
22. Cole DC, Ibrahim SA, Shannon HS, Scott F, Eyles J. Work correlates of back problems and activity restriction due to musculoskeletal disorders in the Canadian national population health survey (NPHS) 1994-5 data. Occup Environ Med. 2001 Nov;58(11):728-34.
23. Troup JD, Martin JW, Lloyd DC. Back pain in industry. A prospective survey. Spine. 1981 Jan-Feb;6(1):61-9.
24. Abenhaim L, Suissa S, Rossignol M. Risk of recurrence of occupational back pain over three year follow up. Br J Ind Med. 1988 Dec;45(12):829-33.
25. Hestbaek L, Leboeuf-Yde C, Engberg M, Lauritzen T, Bruun NH, Manniche C. The course of low back pain in a general population. Results from a 5-year prospective study. J Manipulative Physiol Ther. 2003 May;26(4):213-9.
26. Enthoven P, Skargren E, Oberg B. Clinical course in patients seeking primary care for back or neck pain: A prospective 5-year follow-up of outcome and health care consumption with subgroup analysis. Spine. 2004 Nov 1;29(21):2458-65.
27. Ferguson SA, Marras WS, Burr DL. Differences among outcome measures in occupational low back pain. J Occup Rehabil. 2005 Sep;15(3):329-41.
28. Wasiak R, Kim J, Pransky G. Work disability and costs caused by recurrence of low back pain: Longer and more costly than in first episodes. Spine. 2006 Jan 15;31(2):219-25.

29. Ricci JA, Stewart WF, Chee E, Leotta C, Foley K, Hochberg MC. Back pain exacerbations and lost productive time costs in United States workers. Spine. 2006 Dec 15;31(26):3052-60.
30. Lavis JN, Malter A, Anderson GM, Taylor VM, Deyo RA, Bombardier C, et al. Trends in hospital use for mechanical neck and back problems in Ontario and the United States: Discretionary care in different health care systems. CMAJ. 1998 Jan 13;158(1):29-36.
31. Mustard C, Cole D, Shannon H, Pole J, Sullivan T, Allingham R. Declining trends in work-related morbidity and disability, 1993-1998: A comparison of survey estimates and compensation insurance claims. Am J Public Health. 2003 Aug;93(8):1283-6.
32. Barker ED, Tremblay RE, Nagin DS, Vitaro F, Lacourse E. Development of male proactive and reactive physical aggression during adolescence. J Child Psychol Psychiatry. 2006 Aug;47(8):783-90.
33. Herrenkohl TI, Hill KG, Hawkins JD, Chung IJ, Nagin DS. Developmental trajectories of family management and risk for violent behavior in adolescence. J Adolesc Health. 2006 Aug;39(2):206-13.
34. Nagin DS, Tremblay RE. Developmental trajectory groups: Facts or a useful statistical fiction? Criminology. 2005;43(4):873-904.
35. Waxman R, Tennant A, Helliwell P. A prospective follow-up study of low back pain in the community. Spine. 2000 Aug 15;25(16):2085-90.
36. Elders LA, Burdorf A. Prevalence, incidence, and recurrence of low back pain in scaffolders during a 3-year follow-up study. Spine. 2004 Mar 15;29(6):E101-6.
37. Kopec JA, Sayre EC, Esdaile JM. Predictors of back pain in a general population cohort. Spine. 2004 discussion 77-8; Jan 1;29(1):70-7.
38. Croft PR, Papageorgiou AC, Thomas E, Macfarlane GJ, Silman AJ. Short-term physical risk factors for new episodes of low back pain. prospective evidence from the South Manchester back pain study. Spine. 1999 Aug 1;24(15):1556-61.
39. Dembe AE, Savageau JA, Amick BC,3rd, Banks SM. Office-based medical care for work-related conditions: Findings from the national ambulatory medical care survey, 1997-1998. J Occup Environ Med. 2002 Dec;44(12):1106-17.
40. Shannon HS, Lowe GS. How many injured workers do not file claims for workers' compensation benefits? Am J Ind Med. 2002 Dec;42(6):467-73.
41. Morse TF, Dillon C, Warren N, Levenstein C, Warren A. The economic and social consequences of work-related musculoskeletal disorders: The Connecticut upper-extremity surveillance project (CUSP). Int J Occup Environ Health. 1998 Oct-Dec;4(4):209-16.
42. Hertzman C, McGrail K, Hirtle B. Overall pattern of health care and social welfare use by injured workers in the British Columbia cohort. Int J Law Psychiatry. 1999 Sep-Dec;22(5-6):581-601.
43. Wasiak R, Pransky G, Verma S, Webster B. Recurrence of low back pain: Definition-sensitivity analysis using administrative data. Spine. 2003 Oct 1;28(19):2283-91.