Back Injuries in Heavy Industries:
Risk Factor Exposure Assessment

Back Injuries in Heavy Industries, Part B:
Risk Factor Exposure Assessment

Final Report to WorkSafeBC

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Main Messages

Many British Columbians employed in heavy industries will suffer from back injuries over the course of their careers. Occupational back injuries are very common in this province, and they are also very costly due to lost workdays, compensation claims, and health care costs.

Although many studies have investigated back injuries and their risk factors, the research community has not reached a consensus on the occupational causes. In part, this is because exposures are difficult to measure in large numbers of people in real work settings.

We tested five approaches to measuring exposures in the following heavy industries: forestry; wood and wood products; construction; transportation; and warehousing.

Three methods used measurement instruments:
- an "inclinometer" to measure **posture** for the full work shift;
- "electromyography" (EMG) to measure **back muscle activity** for the full shift;
- a vibration meter to measure "**whole body vibration**" on vehicle seats when the participant was in the vehicle.

Of these methods, the inclinometer was most feasible to use in the challenging work environments typical of heavy industry (e.g., being out in the weather, changing work tasks and body positions). It collected several measurements (forward and backward bending angles, side-to-side bending angles, and speed of trunk movements).

Two methods did *not* use instruments:
- **observations** by trained observers of postures, lifting, vehicle use, and tasks for the full shift;
- end-of-shift **interviews** of employees about postures, lifting, and vehicle use during the shift.

Both were feasible to use. Interviews were the least costly of all the methods tested.

We also tested to see whether **statistical models** could be derived to estimate the exposures measured by the instruments, using information collected via the less expensive interview and observation techniques. Overall, the observation data did a reasonable job of predicting the measurements that were taken with the various instruments. In most cases, the interview data did not predict the instrument measurements as well.

Depending on the aims, locations, and budget, **studies of back injuries could be best served by using a combination of exposure assessment techniques**. The following combination could work well in heavy industry settings: observations to collect information about lifting, vehicle use, and tasks; and inclinometry to measure postures and movement speeds in detail.

This study also provided data about exposures to back injury risk factors in British Columbia across many different jobs in the five heavy industries. Floor layers, construction labourers, bricklayers, bus cleaners, and fallers had consistently high posture and muscle activity exposures. Heavy equipment operators had the highest vibration exposures.

Executive Summary

Back disorders are among the most common and costly occupational injuries in British Columbia. They are also very difficult to study, and researchers agree that improving exposure assessment methods is key to better understanding the risk factors for back disorders.

The primary goal of this study was to identify feasible and low-cost exposure measurement techniques for use by health researchers studying the causes of back disorders. To accomplish this goal, we took exposure measurements of 126 workers employed in five major heavy industries in British Columbia using five different exposure assessment methods. Three of these methods used instruments that took direct measurements of some of the most important risk factors for back disorders: posture and bending (measured by an "inclinometer"); muscle activity due to both posture and lifting (measured by "EMG"); and vibration of the body due to operating a vehicle (measured by a vibration meter). The other two methods gathered less detailed yet wider-ranging information about risk factors: via once-per-minute observations of work; and via end-of-shift interviews of workers about their exposures.

By collecting five types of exposure data from workers in many jobs in different industries, we were able to address the following questions:

- Which of the measurement methods is most feasible and least costly when used in these diverse industries?
- What levels of exposure, as measured by instruments, do workers experience in different job types and different industries?
- Can data collected through observation and interview be used to predict exposures measured by instruments?

Feasibility and cost of measurement methods

The results of our data collection and analysis show that that the observation and interview methods were most feasible in the diverse settings of heavy industry; that is, they produced the greatest amount of usable data over the 223 shifts when measurements were attempted. These two methods were also the least costly of the five used, primarily because they did not involve the capital investment and maintenance costs associated with specialized instruments.

A number of factors associated with gathering exposure measurement data influenced the feasibility and cost of the various methods. Workers in BC's heavy industries operate in a wide range of settings, many of which are affected by extreme and unusual conditions, tasks, and postures. Many of these variables limited the usability of the measurement instruments we used. For example, the seats in log boom boats are sometimes fully immersed in water. We decided not to use our electronic vibration monitoring instrument in these conditions. Hot and humid conditions in paper mills cause workers to sweat, making it uncomfortable and difficult to wear measurement instruments (for example, EMG electrodes could become detached from the skin).

The measurement instruments that we used were not well suited for some of the conditions faced at worksites. The subzero temperatures in cold storage warehouses caused electronic instruments to fail, and workers with active jobs sometimes inadvertently damaged instrumentation attached to their bodies. A significant amount of money and time was lost due to equipment failure. Worksite challenges also affected observation and interview methods, but to a lesser extent.

In summary, our fieldwork showed that, of the 5 methods we tried, observations and interviews were the most feasible and lowest cost for measuring exposures in these industries. Of the three instruments used, the most feasible and lowest cost was the inclinometer, which measures posture. In future studies, using an inclinometer and observations might complement each other, since the inclinometer offers detailed data on postures and trunk movement speed, and observations provide a breadth of data on materials handling, vehicle use, and tasks.

Exposure by industry and job type

Our fieldwork resulted in extensive measurements relating to posture and bending, muscle activity, and whole body vibration in the five heavy industries. Using statistical techniques, we were able to compare exposures across industries and across job types.

For example, our analysis of industries showed that construction workers, on average, had the highest exposures to bent postures. Workers in the forestry and wood products industries who operated heavy equipment or drove trucks, on average, had the highest exposures to whole body vibration.

Our analysis showed a high level of exposure variability within industries, making it valuable to examine exposures by job. Floor layers, construction labourers, bricklayers, bus cleaners, and fallers had consistently high posture and muscle activity exposures. Heavy equipment operators had the highest exposures to vibration compared to operators of other vehicles.

Predicting exposures with observations & interviews

The final part of our analysis involved developing statistical equations to determine whether the most feasible and lowest cost methods, observations and interviews, could be used to predict the data measured by the instruments. Overall, the observation data did a reasonable job of predicting the measurements that were taken with the various instruments. In most cases, the interview data did not predict the instrument measurements as well. The observations and interview data were able to explain between 30% and 61% of the variability in the measurements taken by the instruments. These equations could be used to predict posture, muscle activity, and vibration exposures in studies of back injuries where instrumental measurements are not performed, but there will be a loss in accuracy. Further testing is required to determine how well these prediction equations would work in other worksites, and, especially, in other industries.

Conclusions

Choosing a method for measuring potential back injury risk factors involves many considerations, such as the purpose of the measurements, the environment in which the measurements will be taken, and budget. In this report, we compare the five techniques investigated in this study, but we do not discuss other measurement methods used in the ergonomics field (such information will be available in our academic publications).

Our study results show that, of the five techniques, three were more feasible and less costly within the heavy industry environments we studied: interviews; observations; and inclinometry. We suggest that a combination of data collection methods such as inclinometry and observations may be a good choice in future back injury studies in heavy industries. This combination would allow

- measurement of forward and backward bending, side-to-side bending, and trunk movement speed in a great deal of detail, using the inclinometer;

- collection of a breadth of data on tasks, manual materials handling, and vehicle use, via observations; and
- partial prediction of muscle activity and vibration exposure levels, using the observations and the prediction equations (explaining up to 47% of the variance in exposures measured by the EMG or vibration meter).

1. Context

1.1 The study components

This report describes the results of the study "*Back Injuries in Heavy Industries, Phase 1,* **Part B: Risk Factor Exposure Assessment.**" The primary purpose of this part of the study was to identify exposure measurement techniques that would be as accurate and feasible as possible for use in occupational studies of the causes of back disorders. The exposures of interest were the following, all believed to increase the risk of back disorders:

- body postures;
- manual materials handling; and
- whole body vibration.

This study has also provided a dataset describing these exposures in the five heavy industries studied:

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

To assess exposures, we used measurement instruments, observations of work by experts, and interviews of study participants. This report presents how we conducted the exposure assessments; the successes, challenges, and costs of the various assessment techniques; the levels of exposure by job and industry; and information about how well observations of work and interview data can estimate measured exposures.

The other component of this study "*Back Injuries in Heavy Industries, Phase 1,* **Part A, Defining Back Injury Outcomes for Research Purposes**" is reported separately. The two parts of this study comprise Phase 1 of a research program aiming to understand the causes of back disorders. We hope to use the results of this phase to design Phase 2, a study aimed at better understanding the causes of back disorders.

1.2 Why back injuries are important

Back disorders 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 [WorkSafeBC, 2006]. 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]=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 disorders: materials handling, body postures, and whole body vibration.

1.3 Why improved exposure assessment is needed

There have been over one hundred studies of the occupational causes of back disorders [see reviews by Frank *et al.*, 1996; Burdorf & Sorock, 1997; Bovenzi & Hulshof, 1999; Lings & Leboeuf-Yde, 2000; Hartvigsen *et al.*, 2000; Lis *et al.* 2006], but there is still controversy about what factors are truly causal. This is because back disorders and their risk factors are surprisingly difficult to study. Part A of this study addresses the difficulties in assessing back disorders themselves. Part B, the subject of this report, addresses the difficulties in exposure assessment.

The best health studies include large numbers of workers with a wide variety of exposures, so that comparisons can be made between individuals with high exposures and those with low exposures, using data from multiple work shifts. Detailed exposure measurements, using instruments, are often labour and capital intensive, so they are usually most easily made on small groups of workers in a single workplace over short durations. As a result, back injury research has often used other methods that can also present problems, as discussed and studied by many investigators [see, for example, Burdorf & van der Beek, 1999; Genaidy *et al.*, 1994; Guangyan & Buckle, 1999; Hansson *et al.*, 2006; Magnusson *et al.*, 1998; Marras, 2005; Neumann *et al.*, 1999; Spielholz et al., 2001; van der Beek & Frings-Dresen, 1998; Wells *et al.*, 1994, 1997; Wiktorin *et al.*, 1999]:

- Job titles have been used as a surrogate of exposure, but this makes it difficult to interpret which risk factors are causing any injuries identified.
- Observations and questionnaires are often used. Their value depends on the questions and observations made and how well they are related to the exposure of interest.
- Measurements of less than one shift in duration may be extrapolated to apply to longer work periods.
- Measurements of a very small sample of jobs (or equipment) may be extrapolated to the larger workforce being studied.
- Exposure assessments may consider only one of multiple possible risk factors.

A number of approaches might help to make exposure assessment for back injury studies easier, and therefore more feasible for large numbers of study subjects in a wide array of industries:

- compact, portable, easy-to-use instruments that record exposures over long periods;
- observations of risk factors by experts that are reliable (i.e., repeatable from observer-to-observer) and valid (i.e., accurately reflect measured exposures);
- self-reports of risk factors by study subjects that are reliable and valid; and
- "determinants of exposure models" to predict exposure levels using data collected from observations and/or interviews.

To evaluate these approaches, this study used five different exposure assessment techniques:

- measurements using an instrument that quantifies body postures (inclinometry);
- measurements using an instrument that quantifies muscle activity (electromyography or "EMG");

[1] RR = relative risk' in this case RR=1 means an industry with average back injury risk, and RR greater than 1 indicates an industry with higher than average risk

- measurements using an instrument that quantifies whole body vibration (vibration meter);
- observations by experts of tasks, body postures, materials handling, and driving; and
- interviews of study subjects about jobs, postures, materials handling, and driving.

The aim was to identify exposure assessment methods that were the most feasible and least costly, and could be used in a large-scale study of the causes of back disorders across different occupations and work environments.

By improving the research community's capacity to conduct worksite measurements in a wide range of occupational environments, it is our hope that more and better research about the causes of back disorders can be conducted. A large body of research evidence is necessary to make evidence-based recommendations about interventions to prevent back disorders. By improving the way we assess workers' exposure to back injury risk factors, we will help workers' compensation systems assess occupational back injury claims, and we will provide workplaces with strategies they can use to reduce exposures that cause back disorders in their facilities.

2. Approach

2.1 Study participants

Study participants were selected in two ways. First, to achieve a sample from a wide range of worksites in the industries of interest, a random sample of injured workers with a back-related compensation claim in the year 2001 was selected from the records of WorkSafeBC. To meet the requirements of the Freedom of Information and Protection of Privacy Act of BC, the Research Secretariat of WorkSafeBC first telephoned the selected injured workers to request their permission to give their names and contact information to the University of British Columbia (UBC) study team. The following outlines the procedures and numbers:

- 338 injured workers were successfully contacted;
- 189 were willing to release information to the research team;
- 155 were successfully contacted by the team;
- 105 were eligible (still working in one of the five heavy industries and in the study region, i.e., Greater Vancouver and the Sunshine Coast);
- 74 agreed to participate
- 54 were successfully measured after contacting the employer for their permission to conduct field work on their site. The number of injured workers included in the study met our target of 50.

The second method of participant selection was selection of 1 to 3 co-workers of each injured worker. This resulted in an additional 72 study participants.

All participants were informed about the study purpose and procedures via letter and phone conversations, and were given information about how their privacy and workplace information would be protected. The research team also consulted with employers to answer any questions or concerns they might have, and to describe the benefits of participating in the study. Informational slideshows and leaflets were prepared for both employers and employees. In addition, the study team sent letters describing the study to all unions and employer organizations that had a connection to the target industries. A website (http://www.cher.ubc.ca/backstudy.htm) was set up to provide an ongoing source of information to participants and their employers.

2.2 Measurement methods

The research team took measurements between September 2004 and March 2006 in 50 different workplaces in the five heavy industries of interest. We made measurements of the 126 participants, most of them on two days, for a total of 223 person-days of measurements. The breakdown by industry was:

- 42 days in forestry;
- 42 days in wood and paper products;
- 54 days in transportation;
- 43 days in warehousing; and
- 42 days in construction.

The exposure assessments included shift-long observations by trained observers, a post-shift interview of the participants, and shift-long direct measurements using three different methods: inclinometry; electromyography (EMG); and vibration monitoring. A brief description of these components of our methodology follows.

2.2.1 Measurement instruments

At the beginning of each shift, the instruments were fitted on the worker, calibrated, and tested to ensure accurate measurements. The methods and purpose of each instrument follow on pages 6 - 8.

2.2.2 Observations

Personnel with training in ergonomics made observations of each participant's physical exposures once every minute throughout the shift, excluding work breaks. The observers recorded their observations on paper forms.

The observation form was developed over a 4-month period, using the following steps:

- review of literature about the most important components and determinants of posture, manual materials handling, and vibration;
- comparison of the factors in the observation form to a biomechanical model [Ergowatch 4D WATBAK, 2007];
- testing of the feasibility of making observations at various frequencies (from every 10 seconds to every 10 minutes);
- inter-observer reliability testing using repeated observations of still photos of work tasks, and side-by-side observations of 7 work shifts in field settings; and
- refinement of the observation form.

The final form, the "Back Exposure Sampling Tool" (Back-EST; Appendix A), was used to record observations of tasks, items or power tools held, items worn (such as a tool belt), general body posture (such as standing, walking, kneeling), trunk angles, trunk supports, lateral bending, manual materials handling including the horizontal distance, weight and force of the load, and any additional pertinent comments. When workers were in vehicles, additional observations were made of the vehicle type, terrain, slope, speed, driving style, and vehicle load. Vehicle characteristics were also recorded, including type of vehicle, operating duration, gross vehicle weight, wheel characteristics, type of transmission, seat type, suspension type, back support, armrests, and location of cab in relation to the load (Appendix B). Where possible, photos were taken of the items carried and the vehicles. All observation data was double entered into an electronic database by a data entry firm.

2.2.3 Interviews

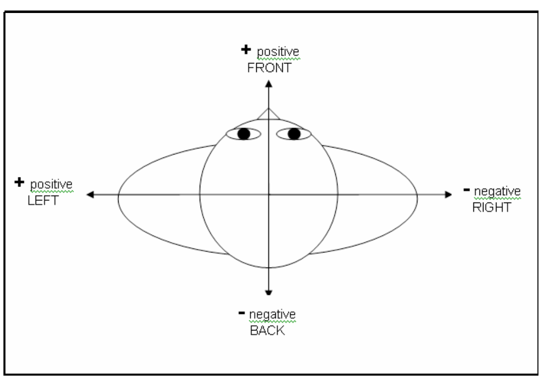
A post-shift interview was conducted with each participant using a structured questionnaire. To the extent possible, the questionnaire was designed to ask about work factors parallel to those in the observation form. The initial questionnaire prototype was pre-tested on 7 university laboratory and facility workers and was modified to ensure questions were understood and feasible to answer at the end of a shift.

The final questionnaire (Appendix C) asked about posture, manual materials handling, whole body vibration, and related exposures. Participants were asked to identify and give estimates of durations of their work activities from drawings of representative postures, materials handling activities, and driving activities. All interview data was double entered into an electronic database by a data entry firm.

Inclinometry

To measure body posture, we used the Virtual Corset inclinometer (VC-323, Microstrain Inc., Williston, VT). It is pictured below, both in close up and as mounted on the chest of a study participant at approximately the level of the sixth thoracic vertebrae. The inclinometer could also be placed on the back to accommodate the work of the participant.

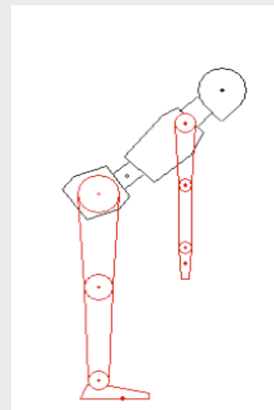
The inclinometer is about the size of a pager. It measured and stored body angles at a rate of 7.6 per second (Hz). Posture was measured throughout the work shift, recorded to a 2 Mb memory chip, and subsequently downloaded to a computer. As shown below, forward bending angles ("flexion") were assigned positive values by the inclinometer, and backward bending angles ("extension") were assigned negative values. Similarly, side-to-side bending angles ("lateral flexion") to the left were positive and to the right were negative, though we used the absolute value of lateral bends in data analyses.



Before and after the workshift, each study participant was asked to stand straight, to bend forward three times, and to bend backwards once, in order to allow adjustments of the data for the angle of the inclinometer on the individual participant's body.

Why is posture important?

Awkward or extreme bending postures, very fast movements, and maintaining the same posture for a long time are all thought to be risk factors for back disorders and pain.

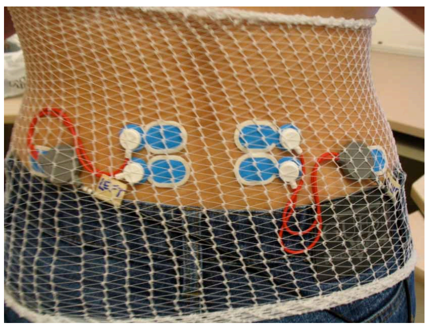


Although we know that forward bending can be a risk factor for back disorders, there are currently no published guidelines for bending postures. Bending forward more than 60° for more than 5% of the working day has been found to be one of the risk factors for low back pain [Hoogendoorn et al, 2000].

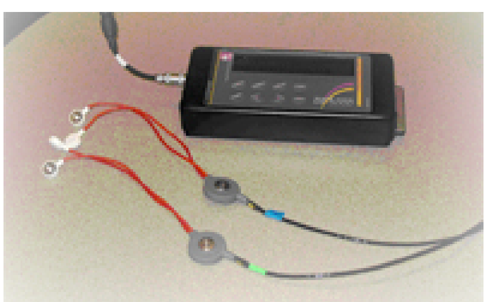
Electromyography (EMG)

Electromyography measures the electrical signals generated by muscles when they contract. This "muscle activity" changes body postures and also supports loads, therefore this type of measurement is related to both posture and manual materials handling (lifting).

We used a portable EMG data collection system that uses electrodes to detect muscle activity. As shown in the photo below, the electrodes (12-mm Ag-AgCl Blue Sensor N-00-S, Ambu, Denmark) were placed 20-mm apart over the fourth and fifth vertebrae of the lumbar spine (lower back).



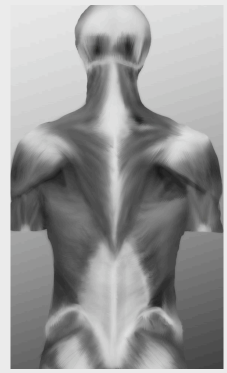
The muscle activity measured by the electrodes was stored using a portable data collection system (photo below) with on-board memory (ME3000P4 and ME3000P8, Mega Electronics, Finland). This instrument was worn in a fanny pack. Signals were collected 1000 times per second (Hz) and the average value was stored 10 times per second. Data were downloaded from the EMG data collection system onto a laptop computer during work breaks.



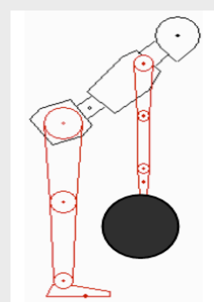
Before and after the workshift, each study participant was asked to stand straight, and to bend forward in 4 positions with and without weights. One of these manoeuvres (described to the right) was used as the "reference contraction."

What is EMG?

Every time the muscles contract, nerves send electrical impulses that can be detected by electrodes on the skin. This kind of measurement is called electromyography or EMG.



Because everyone's skin, muscles, and nervous system are a little bit different, all EMG measurements need to be compared to an individual baseline on the measurement day.



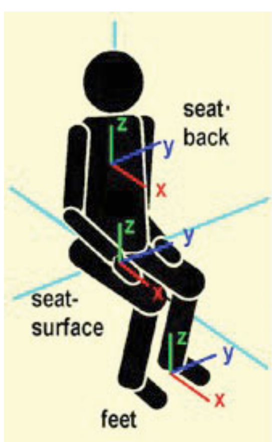
In this study, the muscle activity recorded during a forward bend of 45° while holding an 11.5 kg weight at the beginning of the shift was used as the "reference" for comparison of all EMG measurements made during the shift. All measurements are therefore expressed as percentage of reference contraction or "%RC".

Vibration monitoring

We measured the whole body vibration intensity, frequency, direction, and duration for workers who spent part or all of their shift in a vehicle.

Whole body vibration was measured with a Larson Davis triaxial seatpan accelerometer (black disk shown on the seat below). It was placed on the seat of the vehicle used by the study participant. The vibration signal was averaged and recorded once per second by a Larson Davis Vibration Monitor (IHVM 100, shown on the right below) and later downloaded to a computer.

Vibration was measured in three axes. As shown in the diagram below, X-axis vibration moves front to back, Y-axis vibration moves side-to-side, and Z-axis vibration moves up and down.

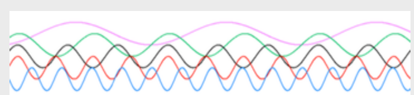


Data were axis- and frequency-weighted according to International Standards Organization ISO 2631-1 (1997) for human response to whole body vibration.

What is Whole Body Vibration (WBV)?

WBV is transmitted through the feet of a standing person, the buttocks of a seated person, or the supported areas of a reclining person. The most common way for employees to be exposed to whole body vibration is when they are in a vehicle, such as a boat, helicopter, truck, forklift, car, or heavy equipment. The effects depend on the intensity, frequency, and duration of exposure to the vibration.

Intensity of vibration is measured as acceleration in meters per second squared (m/s^2)*, and can be thought of as the height of the waves. Taller waves have higher acceleration and more energy. Frequency is the speed of the vibration and is measured as the number of waves "per second" or "Hertz" (Hz). Faster waves have a shorter distance between peaks and have the highest frequency.*



The figure above shows smooth wave forms, but the vibration to which most people are exposed in vehicles includes irregular bumps and jolts.

The human body has a natural (or resonant) frequency of 3 – 5 Hz. Guidelines established by the International Standards Organization (ISO 2631) suggest that for seven hours of continuous work, the magnitude of vibration summed over all axes should not exceed 0.8 m/s^2.

2.3 Data analysis methods

The analyses of the data examined the following issues:

- How feasible was it to use each of the five exposure assessment techniques in diverse work settings, and how much did each cost to use?
- What were the exposure levels, as measured via the three instruments (inclinometer, EMG, vibration monitor), by industry and by job?
- Could the data collected using the observation form and the interview be used to predict the exposures as measured by the three instruments?

All descriptive statistics and ANOVA were performed using SPSS 12 (SPSS Inc., Chicago, IL; analyses 2.3.1 and 2.3.2 described below). Mixed effects regression modeling was performed using SAS 9.1.3 (SAS Institute Inc., Cary, NC; analysis 2.3.3 described below).

2.3.1 Analyzing feasibility and costs

For each of the five exposure assessment methods, measurement feasibility was calculated as the number of person-days with useable exposure data divided by the number of attempted exposure measurement days. An 'attempted day' was defined as a work shift where the exposure measurement method was appropriate for that subject's job. For all methods except vibration, the number of attempted days was 223; for vibration, since not all person-days involved vehicle use, the number of attempted days was 128.

We calculated the estimated costs of each method, including the capital, maintenance, consumables, and personnel expenses associated with data collection and data entry. Certain costs were not included because they would be expected to vary from study to study. Therefore cost estimates did not include expenses associated with training personnel, development of operating procedures, travel to research sites, or data cleaning and analysis. Costs also did not account for the remaining value of the sampling equipment at the conclusion of the study. Personnel costs were calculated for the total measuring time spent on site for each method individually (i.e., without taking into account the economies of scale available to our study because we used multiple measurement methods simultaneously). Personnel costs were based on a research assistant wage ($20/hour) and did not include holiday time or other benefits.

2.3.2 Analyzing exposure levels

After our fieldwork was completed, we had extensive data collected using the three direct measurement instruments. These provided the following measurements:

- forward and backward bending angles, in degrees (inclinometer);
- side-to-side bending angles, in degrees (inclinometer);
- trunk movement speed, in degrees per second (inclinometer);
- spinal muscle activity, as a percent of a reference contraction, i.e., a static 45° forward trunk flexion while holding an 11.5 kg weight (EMG); and
- whole body vibration, in meters per second squared, axis- and frequency-weighted according to the ISO 2631-1 standard (vibration monitor).

We calculated the averages and standard deviations of these measurements for each person-day of measurement, and then calculated the averages and standard deviations for each of the five industries and for each of the jobs held by the participants of the study. Differences in the average exposures between industries and between jobs were examined using one-way analysis of variance

(ANOVA).

2.3.3 Analyzing observation and interview data to predict exposures

The next step in data analysis was to determine whether observations or interview data could be used to predict the measurements recorded by the instruments. The idea was to create equations ("models") such as the following:

Forward and backward bending angle = as measured by the inclinometer	*a + b (% of shift observed walking) + c (% of shift observed carrying object) + d (construction industry)*

We describe the method here using statistical terminology that may be of interest to some readers. For each of the five types of measurements listed in section 2.3.2 above, one equation was created using the observation data and another equation was created using the interview data, for a total of 10 equations. The initial step was to determine in simple linear regression whether each individual independent variable was associated with the measurement in question. If the variable had $p < 0.10$ (for observation variables) or $p < 0.05$ (for questionnaire variables), and was not correlated with other variables (Pearson correlation < 0.70), it was offered to a backwards stepwise multiple linear regression. This method was modified because of the large number of variables, by offering variables in 'conceptual groups'. For example, all posture variables were offered in a group, all vehicle variables were offered in a group, and all demographic variables were offered in a group. The significant ($p < 0.05$) posture variables were offered into subsequent models (e.g., when we added the demographic variables) and only removed if p increased to > 0.10. Models were developed with 'subject' and 'company' as random effect terms to control for within-participant or within-company correlation not accounted for by the fixed effects in the model. All models were checked for influential values using Cook's D.

3. Results and Discussion

3.1 Study participants and worksites

Table 1 outlines the characteristics of the 126 study participants.

Table 1. Characteristics of the study participants

Characteristic	Value	
Average age, in years [SD]	42.1	[11.6]
Average height, in centimeters [SD]	178.3	[7.7]
Average weight, in kilograms [SD]	85.6	[16.2]
Average hours worked per day [SD]	8.5	[1.5]
Average days worked per week [SD]	4.8	[0.7]
Number male [%]	120	[95.2]
Number selected via WorkSafeBC claim in 2001 [%]	54	[42.9]
Number in the forest industry [%]	24	[19.0]
Number in the wood and wood products industry [%]	24	[19.0]
Number in the transportation industry [%]	25	[19.8]
Number in the warehousing industry [%]	30	[23.8]
Number in the construction industry [%]	23	[18.3]

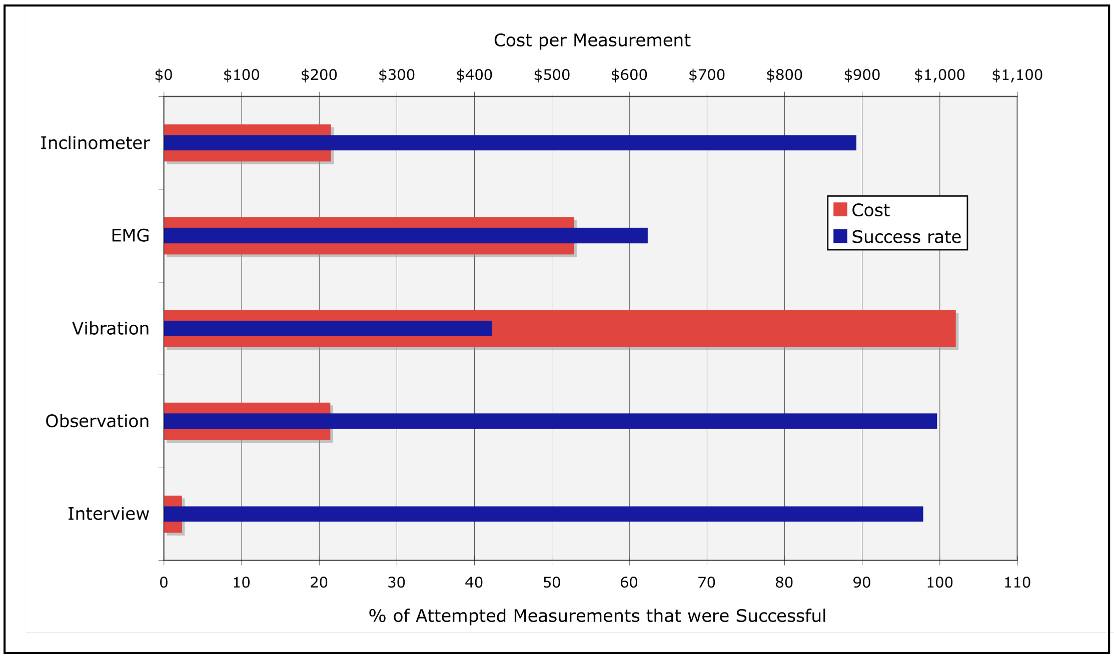
The 50 worksites included in this study were even more diverse than we had hoped, thus the method of recruitment (via randomly selected injured workers) was a success in this regard. Examples of worksites include the following:

- Forestry: tree seed harvesting, logging, vehicle maintenance, log sorting in waterways
- Wood and wood products: sawmills; pulp mills; door, window, and staircase manufacturing
- Transportation: ferries; long haul trucking; aircraft maintenance; baggage handling
- Warehousing: cold storage; container yards; grain elevators
- Construction: road paving; high rise construction; ship building

3.2 Feasibility & costs of exposure assessment methods

Figure 1 shows the proportion of attempted measurements that were successful and the costs of the various exposure assessment techniques. Ideally, an assessment method would have low costs and a high proportion of successful measurements.

Figure 1. Costs and proportion of measurements that were successful for the 5 exposure assessment methods



The observation and interview methods provided the most comprehensive dataset, with 222 (99.6%) observation forms and 218 (97.8%) interviews completed over 223 worker-days. All three types of monitoring equipment had fewer measurements. The virtual corset inclinometer was the most successful, with complete posture data for 199 worker-days (89.2%). EMG was measured for 139 worker days (62.3%); of these, 20 included data for only the left side of the erector spinae muscles and 22 for only the right side. Of the 128 days when participants spent at least 5 minutes at work in a vehicle, whole body vibration was measured successfully on 54 (42.2%).

Interviews were the least expensive method because they demanded the least personnel time. They were 10 times cheaper than observations and inclinometry, the next lowest cost methods. Whole body vibration monitoring and EMG were the most expensive methods, both because of the high capital costs of the monitoring equipment, and because fewer shifts were successfully measured. Because not all workers used vehicles, the cost of measuring whole body vibration was inflated compared to the other measures used in this study. There were no equipment repair charges for the vibration monitor; all repairs needed were covered by warranty. On the other hand, the EMG cables incurred considerable repair costs. There were no data entry costs for the methods using monitoring equipment, since data was stored electronically during the measurement period, and easily transferred to computer later.

3.2.1 Challenges that affected measurement success

A number of challenges affected measurement success, including workplace conditions, work tasks and postures, and damage to equipment. It is useful to outline some of these here, since these issues may influence future choices of exposure assessment methods:

- log boom boats, whose seats were occasionally fully immersed, made it possible to damage electronic *vibration* monitoring equipment (we chose not to risk damage to the equipment, so did not take measurements of these boats);
- in rainfall at forestry and construction worksites, the *EMG* equipment stopped recording, likely due to a short circuit;
- cold storage with temperatures below -25 ^{o}C caused condensation in and halted the function of the *vibration monitor* and stopped ink flow in pens used to record *observations*;
- none of the *measurement instruments* were designed with grounded, arc-free circuits, so they could not be used in the explosive atmosphere of grain elevators;
- hot and humid conditions in paper manufacturing and at outdoor worksites in summer increased participant sweating, which limited *EMG* electrode adhesion and made wearing both the *EMG and inclinometer* uncomfortable;
- participants using lifting belts, tool belts, and fall protection harnesses required careful positioning of the *EMG and inclinometer* and occasional repositioning throughout the day;
- lying down, kneeling, and crawling in maintenance and construction work increased the opportunity for cable movement artifacts and contact interference with *EMG* electrodes;
- at times, the *measurement instruments* were struck or compressed, and cables or harnesses of the *EMG or inclinometer* snagged on scaffolding or machinery; this could have placed the worker at risk of injury and damaged the measurement instruments;
- *observing* dynamic work, such as a participant walking between different tasks or in a single occupant vehicle, challenged the observers to keep up and stay conscious of workplace hazards such as forklift traffic or cranes and wrecking balls;
- both *EMG and vibration* equipment sustained damage as a result of working conditions; repairs to the *EMG*, including delivery time, resulted in 36 lost measurement days;
- the presence of researchers conducting *observations* concerned some participants particularly at the beginning of the first measurement shift;
- the presence of co-workers and supervisors concerned some participants during *interviews* in situations where a private location could not be found.

3.2.2 Scope of measurements

In addition to the costs and feasibility in the field of each method, it is important to consider the scope of each method in terms of the risk factors assessed. The interviews provided a broad overview of exposures to all three risk factors (posture, materials handling, and whole body vibration). The observations did the same, but with more detailed information, since the data were recorded on a minute-by-minute basis, rather than simply at the end of the shift. Each of measurement instruments provided data focused on one risk factor (though EMG provides data on muscle activity due to posture and materials handling), but in tremendous detail (data logging at 1-second or smaller intervals) that could be summarized in many ways (e.g., averages, peaks, percentiles, cumulative exposure, rate of change).

In this study, the observation and interview methods were less expensive and more successfully completed than most methods using monitoring equipment. The difficulties of using monitoring instruments in some workplace conditions, interference with postures and work gear, malfunction, and human error contributed to their lower success in the field, while substantial capital investment was the main factor in their higher cost. However, one monitoring method, inclinometry, was similar in feasibility to observations. Both methods had only moderate costs and nearly complete shift measurements. These two methods were complementary in data detail: observations were broad in scope with information on all the risk factors of interest; and inclinometry provided data depth and precision on postural exposures.

3.3 Instrument-measured exposures in each industry & job

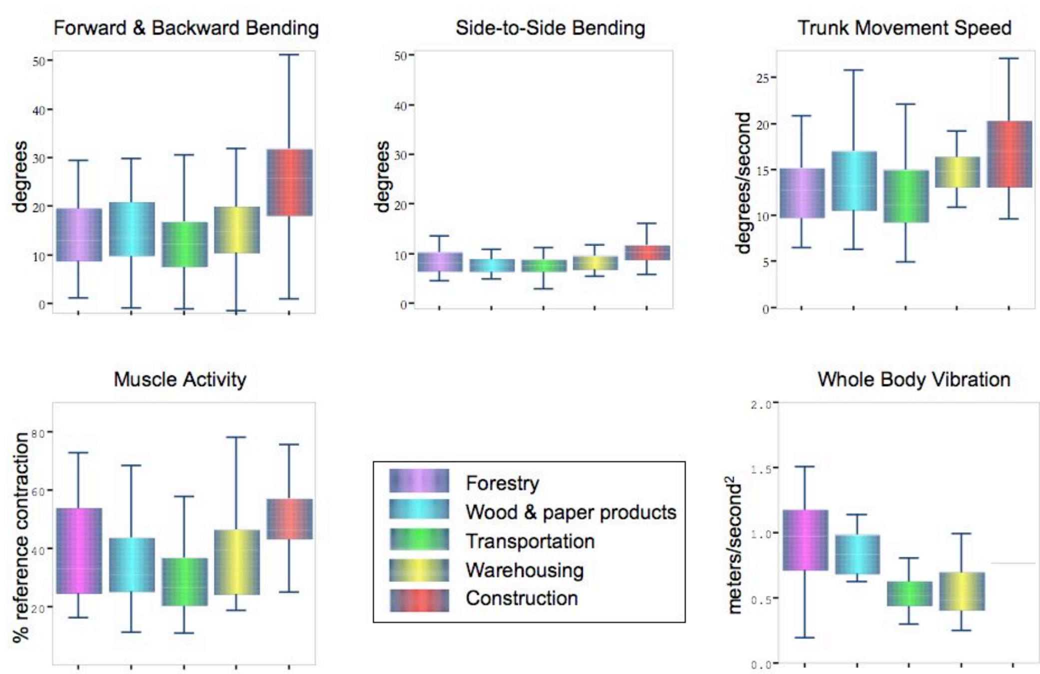
3.3.1 Exposures by industry

Figure 2 shows the average instrument-measured exposures by industry. Based on inclinometer data, participants in the construction industry had higher average forward and backward bending and side-to-side bending than those in all other industries. They also had the highest average trunk movement speed, with the warehousing and wood products industries the next highest. The lowest average trunk movement speed was seen in transportation, which makes sense given the time spent sitting and driving in this industry.

Based on EMG data, participants in the construction industry had higher average muscle activity than those in all other industries. Average muscle activity was the lowest in transportation, again explained by more sedentary driving tasks. Many jobs in warehousing and forestry also had substantial amounts of driving, but there was a great deal of variability in these industries because of the manual materials handling that was observed in most jobs.

Based on vibration monitor data, participants who were in vehicles in the forestry and wood products industries had higher average vibration exposures than those in the other industries.

Figure 2. Box plots of posture, muscle activity, and whole body vibration measurements, by industry (box centre line = median; box top and bottom = 75th & 25th percentiles; top whisker = maximum; bottom whisker = minimum)



3.3.2 Exposures by job

Table 2 lists the average instrument-measured exposures for all jobs combined, and by specific jobs. The highest average forward and backward bending exposures were measured in floor layers and construction labourers, and the lowest in most vehicle occupations and construction supervisors. Average side-to-side bending was highest among bricklayers, helicopter pilots, construction labourers, and bus cleaners, and lowest among heavy equipment operators, construction supervisors and storekeepers and parts clerks. The highest average exposures for trunk movement speed were observed in warehouse persons, construction labourers, bricklayers, log chipper/grinders, and fallers, and the lowest exposures were among vehicle occupations.

Average muscle activities were highest in fallers and construction labourers, and lowest among bus and truck drivers.

Whole body vibration was successfully measured on only 54 days, in part because only about one-half of the study participants used vehicles during their jobs. The highest average vibration exposures were among logging machinery operators (driving front-end loaders, wheel loaders, and skidders), heavy duty equipment mechanics (driving tractor trailers), fallers (driving pick-up trucks on logging roads), and heavy equipment operators (driving front-end loaders, excavators, and yard goats). The lowest exposures, among participants on vehicles, were to a ferry worker (on a large passenger and vehicle ferry), and an airport ramp attendant (driving a pick-up truck on pavement).

3.4 Predicting exposures with observations & interviews

The following sections show the equations that predict the measurements made by the inclinometer, EMG and vibration instruments. To create these prediction equations, we used the data collected either by observing the participants once per minute throughout their shift or by interviewing them about their work activities at the end of the day. The best equations account for a high proportion of the variability in the exposure, as measured by the instrument (this proportion is called R^2).

The equations include industry and/or demographic variables where these added value to the predictions. However, it is important to consider the amount of variance in the measurement data explained by the equations *without* industry in the equation. If industry is in the equation, the equation *cannot* be used for other industries. If it is not in the equation, the equation *might* be applicable to other industries as well.

3.4.2 Forward and backward bending

Table 3 shows the equations predicting forward and backward bending, as measured by the inclinometer, using the observation and interview data.

The observation data produced a prediction equation able to explain over 60% of the variability in the inclinometer's forward and backward bending measurements. Most of the factors that were part of the equation were logical. The following factors were associated with higher inclinometer readings: observations of the trunk at angles of 20° or more, of the trunk twisted or rotated, or of the participant wearing items like tool belts. The following were associated with lower inclinometer readings: observations of the trunk at angles of 10-20°, or using a vehicle (i.e., in a sitting position).

Table 2. Instrument measurements of posture, muscle activity, and whole body vibration, by job

Job	Posture							Muscle Activity (% of reference contraction while in 45° forward flexion and holding a 11.5 kg weight)			Vibration, weighted sum over all axes, (meters/second^2)		
		Forward and Backward Bending (degrees)		Side-to-Side Bending (degrees)		Trunk Movement Speed (degrees/second)							
	N	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**	**N**	**Average**	**SD**	**N**	**Average**	**SD**
All jobs	199	17.0	11.2	8.5	2.6	14.3	4.9	139	39.0	20.5	54	0.70	0.33
Air transport ramp attendants	6	16.0	5.4	7.9	1.0	14.1	3.3	6	28.3	8.3	1	0.39	-
Asphalt worker	4	24.8	11.3	10.5	2.9	15.7	2.6	2	39.3	13.1	0		
Automotive mechanic	8	16.2	3.0	8.6	1.1	11.7	1.4	6	32.9	14.5	0		
Boomman	12	22.5	15.1	7.8	1.7	11.3	4.5	10	31.9	13.4	2	0.64	0.10
Bricklayers	3	22.8	2.0	12.1	1.9	19.2	1.1	1	56.9	-	0		
Bus cleaner	2	20.3	1.2	11.1	0.1	17.5	2.1	1	34.5	-	0		
Bus driver	4	5.8	5.8	9.0	9.4	6.6	2.1	2	14.3	2.4	3	0.48	0.07
Cabinet maker	9	18.1	6.8	8.9	1.7	13.8	2.7	7	51.2	39.1	0		
Construction carpenter	10	24.5	7.6	9.8	1.1	16.5	5.2	7	50.0	10.0	0		
Construction labourer	11	36.4	15.7	11.2	2.3	20.6	4.4	8	66.2	22.3	0		
Construction supervisor	5	7.3	5.1	6.1	1.0	8.4	2.2	5	47.3	16.4	0		
Construction trades, other	3	17.8	3.4	9.9	2.6	12.8	2.0	3	32.4	11.8	0		
Faller	7	12.5	7.6	10.7	1.2	18.2	2.0	4	76.5	18.7	3	0.79	0.33
Ferry worker	9	9.7	4.9	8.5	4.3	10.6	2.7	4	38.1	8.4	1	0.37	-
Floor layer	3	48.4	18.9	11.0	2.4	17.6	1.1	0			0		
Forklift operator	43	15.5	8.5	8.0	2.1	14.8	3.2	31	36.4	20.2	26	0.66	0.33
Heavy equipment operator	7	7.2	6.4	6.7	2.1	11.6	2.0	5	32.4	15.5	4	0.76	0.18
Heavy-duty equipment mechanic	4	17.0	5.2	9.8	2.7	12.7	1.6	4	41.8	11.9	2	0.96	0.30
Helicopter pilot	1	8.8	-	11.8	-	9.3	-	1	33.2	-	0		
Log chipper/grinder	4	21.4	3.8	7.5	1.8	18.6	9.6	2	39.7	40.4	0		
Logging machinery operators	7	10.8	4.9	6.4	1.4	13.9	1.3	4	25.3	5.5	5	1.22	0.20
Lumber grader, puller	9	17.3	8.8	7.8	1.9	17.5	8.0	5	38.5	6.4	0		
Papermaking and coating control operator	8	11.8	4.3	7.3	0.8	12.3	2.3	5	34.3	13.3	0		
Saw filer	2	18.0	7.8	10.0	0.3	11.5	1.1	2	38.6	13.0	0		
Storekeepers and parts clerks	3	14.1	2.4	5.8	1.3	10.8	1.8	3	31.0	17.7	0		
Truck driver	8	8.3	4.2	7.5	2.7	9.2	2.3	7	19.4	6.4	7	0.51	0.22
Warehouse person	7	12.7	8.3	8.5	1.2	21.1	4.6	4	40.7	12.1	0		

N = number of measurement days for the specific job and type of exposure
SD = standard deviation (average deviation of measurements from the average value); - = only one measurement, therefore no SD

Table 3. Equations predicting forward and backward bending, based on observations and on interviews

Measurement being predicted	Equation based on OBSERVATIONS of work activities, and industry & demographic variables N=199	Equation based on INTERVIEWS about work activities, and industry & demographic variables N=193
Forward and backward bending (in degrees) **=**	9.6[a] - 0.052 (% time observed with trunk at 10-20°) + 0.12 (% time observed with trunk at 20-45°) + 0.90 (% time observed with trunk at > 60°) + 0.56 (% time observed with trunk twisted/rotated) - 0.035 (% time observed using vehicle) + 0.050 (% time observed wearing item)	13.1[b] + 0.14 (% time reported crouching) + 0.31 (% time reported walking bent > 60°) + 0.048 (% time reported handling materials) + 11.3 (construction industry) + 1.1 (forest industry) + 1.6 (wood and wood products industry) + 2.6 (warehousing industry)
Percent of the variation in the inclinometer measurements accounted for by this equation	61%	40% (30% without industry in equation)

[a] The average exposure, not including the variables in the equation.
[b] The average exposure, not including the variables in the equation. In this equation, it includes the exposures in the transportation industry.

The interview data produced a less predictive equation; it explained 40% of the variability in the inclinometer's measurements of forward and backward bending when industry was included in the equation, and 30% without (i.e., most of the exposure variability remained unexplained by the observation data). Reports by participants that they spent time crouching, walking bent, and handling materials were associated with higher inclinometer readings. The factors included in the equation are also logical and one variable (walking bent > 60°) is similar to one in the observation equation.

3.3.2 Side-to-side bending

Table 4 shows the equations predicting side-to-side bending, as measured by the inclinometer, using the observation and interview data.

The observation data prediction equation was able to explain only 30% of the variability in the inclinometer's measurements of side-to-side bending, and 5% less than that without industry in the equation. Again, the factors that were part of the equation were logical. The following factors were associated with higher inclinometer readings: observations of bending side-to-side or of handling materials. The following was associated with lower inclinometer readings: observations of the trunk at angles of 10-20°.

The interview data prediction equation explained a similar proportion of the variability in the inclinometer's measurements of side-to-side bending (34%), when industry was included in the equation, and 7% less without. Reports by participants that they spent time lying down, and handling materials were associated with higher inclinometer readings. Sitting was associated with lower inclinometer readings. Surprisingly, self-reported time spent bending side-to-side was not related to the measured amount of bending side-to-side, making it possible that the equation is not robust.

Table 4. Equations predicting side-to-side bending (the absolute value, i.e., bending to either side is positive), based on observations and on interviews

	Equation based on OBSERVATIONS of work activities, and industry & demographic variables N=198	**Equation based on INTERVIEWS about work activities, and industry & demographic variables N=194**
Side-to-side bending (in degrees) **=**	5.7[a]	7.4[a]
	- 0.022 (% time observed with trunk at 10-20°)	- 0.015 (% time reported sitting)
	+ 0.091 (% time observed bending side-to-side)	- 0.023 (% time reported sitting bent sideways)
	+ 0.043 (% time observed handling materials)	+ 0.30 (% time reported lying down)
	+ 1.9 (construction industry)	+ 0.010 (% time reported handling materials)
	+ 1.8 (forest industry)	+ 2.1 (construction industry)
	+ 1.2 (transportation industry)	+ 1.5 (forest industry)
	+ 1.4 (warehousing industry)	+ 0.88 (transportation industry)
		+ 1.2 (warehousing industry)
Percent of the variation in the inclinometer measurements accounted for by this equation	30% (25% without industry in equation)	34% (27% without industry in equation)

[a] The average exposure, not including the variables in the equation. In this equation, it includes the exposures in the wood and wood products industry.

3.4.3 Trunk movement speed

Table 5 shows the equations predicting trunk movement speed, as measured by the inclinometer, using the observation and interview data. This measurement is the speed of forward and backward bending, which was highly correlated with speed of side-to-side bending (Pearson r=0.92).

The observation data prediction equation was able to explain nearly half (46%) of the variability in the inclinometer's measurements of trunk movement speed. The factors associated with higher inclinometer readings were as expected: observations of walking, of trunk angles of 45° or more, of the trunk twisted or rotated, and of handling materials. The following factor was associated with lower movement speeds: observations of the trunk supported. Two interesting and logical demographic characteristics were important: older participants had slower trunk movement speeds, as did participants selected based on an accepted back injury claim.

The interview data produced a similar equation, though it included three fewer variables and explained less variability in the inclinometer's measurements of trunk movement speed: 33%.

It is interesting to note that neither the observations nor interview questions included estimates of movement speed, yet the variables that were measured were still able to predict this speed to a reasonable degree. Both self-reported and observed time spent walking increased the predicted trunk movement speed, perhaps because jobs with more walking tend to be more dynamic and involve faster movements.

Table 5. Equations predicting trunk movement speed, based on observations and on interviews

	Equation based on OBSERVATIONS of work activities, and industry & demographic variables N=199	Equation based on INTERVIEWS about work activities, and industry & demographic variables N=193
Trunk movement speed (in degrees/second) **=**	11.9[a]	18.1[a]
	+ 0.089 (% time observed walking)	- 0.033 (% time reported sitting)
	- 0.020 (% time observed with trunk supported)	+ 0.097 (% time reported walking bent at 45-60°)
	+ 0.32 (% time observed with trunk at 45-60°)	+ 0.39 (% time reported walking backwards)
	+ 0.085 (% time observed with trunk at > 60°)	+ 0.024 (% time reported handling materials)
	+ 0.081 (% time observed with trunk twisted/rotated)	- 0.10 (participant's age)
	+ 0.063 (% time observed handling materials)	
	- 0.080 (participant's age)	
	- 1.30 (participant selected based on accepted back injury claim in 2001)	
Percent of the variation in the inclinometer measurements accounted for by this equation	46%	33%

[a] The average exposure, not including the variables in the equation.

3.4.4 Muscle activity

Table 6 shows the equations predicting muscle activity, as measured by the EMG, using the observation and interview data.

The observation data prediction equation was able to explain 47% of the variability in the EMG's measurements of muscle activity. The following factors were associated with higher inclinometer readings: observations of the trunk at angles of more than 45°, carrying loads of 5 to 20 kg, handling loads at an extended horizontal distance from the body, and standing. Some previous studies have found that bending postures over 60° tend to 'turn off' muscle activity (called the 'flexion-relaxation response') [Sarti *et al.*, 2001; Solomonow *et al.*, 2003]. Since our equation predicts average muscle activity, the apparent discrepancy may be related to the muscle activity required to get into and out of a 60° bend and reflect an overall dynamic job, rather than the muscle activity during a static 60° bend.

The interview data prediction equation explained less of the variability in the EMG's measurements of muscle activity (36%) even with industry included in the equation, and a further 6% less without. Reports by participants that they spent time crouching were associated with higher EMG readings. Sitting and twisting were associated with lower muscle activity. These variables are not as logically expected to be related to muscle activity as those in the equation based on observations, suggesting this equation based on interviews may not be valid.

Table 6. Equations predicting muscle activity, based on observations and on interviews

	Equation based on OBSERVATIONS of work activities, and industry & demographic variables N=138	Equation based on INTERVIEWS about work activities, and industry & demographic variables N=136
Muscle activity (in % of reference contraction while in 45° forward flexion and holding a 11.5 kg weight) **=**	19.8[a] + 0.12 (% time observed standing) + 0.24 (% time observed with trunk at 45-60°) + 0.61 (% time observed with trunk at > 60°) + 0.13 (% time observed handling load at an extended horizontal distance) + 0.91 (% time observed carrying 5-10 kg) + 0.33 (% time observed carrying 10-20 kg) + 0.24 (% time observed with a light push or pull force)	33.4[b] - 0.18 (% time reported sitting) - 0.23 (% time reported sitting and twisting) + 0.20 (% time reported crouching, kneeling or squatting) + 14.8 (construction industry) + 13.3 (forest industry) + 4.4 (wood and wood products industry) + 8.8 (warehousing industry)
Percent of the variation in the EMG measurements accounted for by this equation	47%	36% (30% without industry in equation)

[a] The average exposure, not including the variables in the equation.
[b] The average exposure, not including the variables in the equation. In this equation, it includes the exposures in the transportation industry.

3.3.5 Whole body vibration

Table 7 shows the single equation predicting whole body vibration. In this case, although driving activities were observed during the shift and queried on the post-shift questionnaire, the resulting variables did not enter the equations. The final equations for both observation and interview data ended as identical models including only vehicle type and industry variables.

The equation explained 46% of the variability in the vibration data (24% without industry in the equation). The highest vibration exposures were from heavy equipment, followed by trucks, buses, pickup trucks, forklifts, and boats. Buses had the lowest vibration exposures and are represented in the constant in the equation. The type of vehicle is a promising way to distinguish vibration exposure levels, since vehicle information is easy to collect. After adjusting for vehicle type, the wood and wood products industry had the highest exposures, followed by construction, forestry, warehousing and transportation.

Table 7. Equation predicting whole body vibration (during the time spent on the vehicle only). Note that equations based on observations and on interviews were identical, since no questionnaire or observation data stayed in the models

	Equation based on OBSERVATIONS or INTERVIEWS of driving activities, vehicle information, vehicle type, demographic, and industry variables N=54
Whole body vibration (in meters/sec^2) **=**	0.47 [a]
	+ 0.50 (vehicle is heavy equipment)
	+ 0.17 (vehicle is a truck)
	+ 0.12 (vehicle is bus)
	+ 0.11 (vehicle is pickup truck)
	+ 0.093 (vehicle is forklift)
	+ 0.38 (wood and wood products industry)
	+ 0.20 (construction industry)
	+ 0.18 (forest industry)
	- 0.11 (transportation)
Percent of the variation in the vibration monitor measurements accounted for by this equation:	46% (24% without industry in equation)

[a] The average exposure, not including the variables in the equation. In this equation, it includes the exposures on boats and in the warehousing industry.

4. Implications

The findings of this study are primarily relevant to occupational health researchers and occupational health professionals in industry.

4.1 Implications for research

The results of our study may useful to other researchers who are embarking on epidemiological studies to measure risk factors for occupational back disorders. This report is not written in detail for the research audience, and it lacks a discussion of the results with comparisons to the international scientific literature. Our academic publications will cover the study methods and results in considerably more depth, including sampling strategy issues such as the components of variance. They will also include comparisons to the publications of other investigators examining exposure assessment for back injury epidemiology. Academic publications that are published, in press, or in progress to January 2008 are listed in section 5 of this report.

The following is a summary of study elements described in this report that may be useful to other researchers. Of the five methods we used to assess exposure (observations of work shifts; post-shift interviews of workers; inclinometry; EMG; and vibration monitoring), the following were the most feasible and least costly:

- Observations and interviews were the methods most easily used in the field, with only one observation and five interviews missed in 223 sampling days. Of the direct measurement instruments, the inclinometer was as feasible to use in field conditions as the paper-based methods. It measures one of the three risk factors of interest, posture, in detail, including forward and backward bending, side-to-side bending, and trunk movement speed, but does not measure muscle activity or vibration. EMG and vibration monitoring were less robust in the heavy industry environments encountered in this study.
- Interviews were by far the least expensive method used, nearly one order of magnitude less costly per successful measurement than inclinometry and observations, the methods that were the next least expensive. EMG was almost twice the cost of inclinometry. Vibration monitoring was about twice as costly as electromyography, in part because few participants operated vehicles (making the comparison less fair).

It is important to note that cost and feasibility in field are only two criteria for comparing measurement methods. The breadth of data and the degree of detail are also important factors to consider. The observations and interviews offered the former, whereas the monitoring instruments offered the latter.

Models to predict exposures, developed in this study, might allow data collected through less expensive methods, such as observations, to predict results from direct measurement instruments. The models that explained the most variability in measured exposures were those using observations to predict forward and backward bending, trunk movement speed, and muscle activity. These accounted for between 46% and 61% of the variability in exposure, as measured by the instruments, and were not dependent on including industry in the equation. The other equations predicted smaller amounts of the variability in the instrument measurements, or required industry as a variable in the model. The models should be further tested by comparing their predictions to exposures measured in new worksites.

Researchers interested in testing or using the prediction equations would be welcome to use the Back-EST observation tool as the basis for taking observations.

4.2 Implications for industry

This study may be useful to occupational health professionals responsible for preventing back disorders in industry. Professionals may find the information about measurement techniques useful. They are also welcome to use the Back-EST observation tool.

In addition, this study provides data about levels of exposure to certain potential back injury risk factors in the five heavy industries measured. These data may be useful to alert professionals about industries and jobs with higher exposures:

- Forward and backward bending angles were highest in the construction industry, and in floor layers, construction labourers, construction carpenters, asphalt workers, bricklayers, boommen, log chipper/grinders, and bus cleaners.
- Side-to-side bending angles were highest in the construction and forest industries, and in bricklayers, helicopter pilots, construction labourers, bus cleaners, floor layers, fallers, asphalt workers, and saw filers.
- Trunk movement speeds were highest in the construction industry, and in warehouse persons, construction labourers, bricklayers, log chipper/grinders, fallers, floor layers, bus cleaners, and lumber graders/pullers.
- Back muscle activities were highest in the construction and forest industries, and in fallers, construction labourers, bricklayers, cabinet makers, and construction carpenters.
- Whole body vibration exposures were highest in the forest and wood products industries, and among logging machinery operators (driving front-end loaders, wheel loaders, and skidders), heavy duty equipment mechanics (driving tractor trailers), fallers (driving pick-up trucks on logging roads), and heavy equipment operators (driving front-end loaders, excavators, and yard goats).

5. Dissemination

The knowledge exchange portion of this study is being conducted in collaboration with the Centre for Health and Environment Research (CHER) at the University of British Columbia. CHER has a mandate to make relevant research information available and accessible for practice, planning, and policy-making. Knowledge transfer activities have targeted several stakeholder groups in multiple ways.

Links to many of the following presentations, reports, and publications are found on the study website: www.cher.ubc.ca/backstudy.htm

5.1 Lay audiences

- Individual reports, providing a summary and description of measurement results, were sent to workers who requested them.
- This report, in full, will be sent to participating workers and worksites, and WorkSafeBC. Lay language summaries included as part of this report were prepared in collaboration with CHER and targeted to industrial workplace health and safety employees/joint health and safety committee members.
- The UBC Back Study website (http://www.cher.ubc.ca/backstudy.htm) was prepared in collaboration with CHER and has already been promoted to research and stakeholder groups. To date, this website has had over 50,000 hits and an average of ten visitors/day.

5.2 Professional audiences

- Presentations upon request to local meetings and seminars, targeting members of professional organizations such as the Association of Canadian Ergonomists and the American Industrial Hygiene Association who could make use of the new method in workplaces. We also hope to have the opportunity to speak to relevant personnel at WorkSafeBC. Presentations include the following to date:
    - Trask C, Teschke K, Chow Y, Village J, Koehoorn M. Can observations and interviews be used to assess 90th percentile and cumulative back muscle loads in heavy industry? 38th Annual Conference of the Association of Canadian Ergonomists, Toronto, October 2007
    - Van Driel R, Trask C, Chow Y, Village J, Johnson P, Koehoorn M, Teschke K. A comparison between electromyography (EMG) and inclinometer predicted spinal compression. 38th Annual Conference of the Association of Canadian Ergonomists, Toronto, October 2007
    - Village J, Trask C, Morrison J, Johnson P, Teschke K, Koehoorn M. Whole-body vibration measurements in the BC forestry and transportation industries. Association of Canadian Ergonomists (ACE) 37th Annual Conference, Banff Alberta, October 22-25, 2006.
    - Trask C, Village J, Morrison J, Johnson P, Teschke K, Koehoorn M. How long is long enough? Physical exposure estimates and sampling duration. Association of

Canadian Ergonomists (ACE) 37th Annual Conference, Banff Alberta, October 22-25, 2006

- Trask C, Cooper J, Teschke K, Luong N, Koehoorn M. Direct recruitment of workers and worksites in heavy industry for occupational field studies. Canadian Association for Research on Work and Health, St. John's, Nfld, June 2006
- Trask C, Luong N, Koehoorn M. Development and testing of an observation tool for occupational ergonomic exposure assessment in heavy industry. Canadian Association of Research on Work and Health Conference, Vancouver, BC, Canada, 2005
- Trask C, Morrison J, Village J. Comparing EMG calibration methods for occupational field studies. Association of Canadian Ergonomists Annual Conference, Halifax, NS, Canada, 2005

5.3 Scientific audiences

- International and national conference presentations, including the following to date:
  - Trask C, Koehoorn M, Village J, Johnson P, Chow Y, Teschke K. Evaluating the efficiency of exposure assessment methods: cost, feasibility, and overcoming challenges in the field. PREMUS2007: Sixth International Conference on Prevention of Work-related Musculoskeletal Disorders. Boston, USA; August 27-30, 2007
  - Trask C, Koehoorn M, Village J, Johnson P, Chow Y, Teschke K. Modeling determinants of low back exposures in construction, forestry, transportation, warehousing and wood products industries. PREMUS2007: Sixth International Conference on Prevention of Work-related Musculoskeletal Disorders. Boston, USA; August 27-30, 2007
  - Johnson P, Ploger J, Trask C, Village J, Chow Y, Koehoorn M, Teschke K. Longitudinal exposure assessments of low back posture in five heavy industries in British Columbia. PREMUS2007: Sixth International Conference on Prevention of Work-related Musculoskeletal Disorders. Boston, USA; August 27-30, 2007
  - Teschke K, Johnson P, Trask C, Chow Y, Village J, Koehoorn M. Measuring Posture for Epidemiology: Comparing Inclinometry, Observations, and Self-Reports. EPICOH2007: 19th International Conference on Epidemiology in Occupational Health. Banff, Canada: October 9-12, 2007
  - Trask C. BC Back Study: Evaluating ergonomic assessment methods for occupational field studies. School of Occupational and Environmental Hygiene Seminar Series. Vancouver, January 12, 2007
  - Trask C, Koehoorn M, Village J, Morrison J, Teschke K, Ploger J, Johnson PW. Evaluating full-shift low back EMG and posture measurement for epidemiological studies. IEA2006, 16th World Conference on Ergonomics. Maastricht, the Netherlands. July, 2006
  - Trask C, Koehoorn M, Village J, Teschke K, Johnson PW. Modeling determinants of working exposures and exposure variability. IEA2006, 16th World Conference on Ergonomics. Maastricht, the Netherlands. July, 2006

- Publications in peer-reviewed, indexed scientific journals, including the following (in preparation, submitted, in press, or published) to date:
    - Teschke K, Johnson P, Trask C, Chow Y, Village J, Koehoorn M. Measuring posture for epidemiology: Comparing inclinometry, observations, and self-reports. In preparation
    - Trask C, Teschke K, Village J, Morrison J, Village J, Johnson P, Koehoorn M. Predicting mean, 90th percentile, and cumulative low back muscle activity in heavy industry employees. In preparation
    - Trask C, Teschke K, Morrison J, Koehoorn M. Optimizing sampling strategies: Components of low-back EMG variability in five heavy industries. In preparation
    - Koehoorn M, Trask C, Cooper J, Luong N, Knott M, Teschke K. Recruitment of workers for occupational health studies. In preparation
    - Village J, Trask C, Luong N, Chow Y, Johnson P, Koehoorn M, Teschke K. Development and evaluation of an observational back exposure sampling tool (Back-EST) for work-related back injuries. Submitted to *Applied Ergonomics*
    - Trask C, Teschke K, Village J, Johnson P, Koehoorn M. How long is long enough? Evaluating sampling durations for low-back EMG assessment. Submitted to *Journal of Occupational & Environmental Hygiene*
    - Johnson PW, Ploger H, Trask C, Teschke K, Koehoorn M, Townsend C. Assessment of a continuous portable ambulatory posture measurement device *Journal of Electromyography and Kinesiology* In press
    - Trask C, Teschke K, Village J, Chow Y, Johnson P, Luong N, Koehoorn M. Evaluating methods to measure low back injury risk factors in challenging work environments. *American Journal of Industrial Medicine* 2007;50:687-696
- Scientific reports, including the following to date:
    - Luu T, Li D, Hodgson M. Literature review – Active and passive vehicle seat suspension systems. (2004)

6. Further Research

Of the direct measurement instruments, the inclinometer was the most successfully used in heavy industry environments and the least costly. It tracks three aspects of posture: forward and backward bending angles; side-to-side bending angles; and trunk movement speed. We noticed in preliminary analyses that posture measurements with this instrument seemed to parallel muscle activity measurements by the EMG. Muscle activity measurements are often used to estimate spinal compression, the force that squeezes the bones in the spine together as we sit, walk, stand, play, and work, and a recognized risk factor for back disorders. This has led us to propose a further investigation of the utility of this instrument: we are investigating the potential to use the inclinometer to estimate spinal compression.

We plan to continue the program of research begun with the Phase 1 study reported here, and will design studies for Phases 2 and 3 of the program. Phase 2 will investigate the relative importance of the many postulated risk factors and their interactions in the etiology and progression of acute and chronic back disorders in heavy industry. We hope to use this data to design control measures. Phase 3 will be a randomized workplace trial of the effectiveness of various control measures to reduce the risk of work-related back disorders.

7. References

Bovenzi M, Hulshof CT. An updated review of epidemiologic studies on the relationship between exposure to whole-body vibration and low back pain (1986-1997). *International Archives of Occupational & Environmental Health* 1999;72(6):351-65

Burdorf A, van der Beek A. (1999) Exposure assessment strategies for work-related risk factors for musculoskeletal disorders. *Scand J Work, Environ Health.* 25 Suppl 4:25-30

Burdorf A. Sorock G. Positive and negative evidence of risk factors for back disorders. *Scandinavian Journal of Work, Environment & Health* 1997;23(4):243-56

Ergowatch 4D WATBAK, Waterloo University, Canada http://www.escs.uwaterloo.ca/riskwatch.html (Accessed April 17, 2007)

Frank JW, Kerr MS, *et al.* Disability resulting from occupational low back pain. Part I: What do we know about primary prevention? A review of the scientific evidence on prevention before disability begins. *Spine* 1996;21(24):2908-17

Genaidy A, Davis N, *et al.* (1994) Effects of a job-simulated exercise programme on employees performing manual handling operations. *Ergonomics.* 37(1):95-106

Guangyan L, Buckle P. (1999) Current techniques for assessing physical exposure to work-related musculoskeletal risks, with emphasis on posture-based methods. *Ergonomics* 42(5):674-695

Hansson GA, Arvidsson I, *et al.* (2006) Precision of measurements of physical workload during standardised manual handling. Part II: Inclinometry of head, upper back, neck and upper arms. *J Electromyogr Kinesiol* 16:125-36

Hartvigsen J, Leboeuf-Yde C, *et al.* Is sitting-while-at-work associated with low back pain? A systematic, critical literature review. *Scandinavian Journal of Public Health* 2000;28(3):230-9

Hoogendoorn WE, Bongers PM, *et al.* Flexion and rotation of the trunk and lifting at work are risk factors for low back pain: results of a prospective cohort study. *Spine* 2000;25(23):3087-92

Lings S, Leboeuf-Yde C. Whole-body vibration and low back pain: a systematic, critical review of the epidemiological literature 1992-1999. *International Archives of Occupational & Environmental Health* 2000;73(5):290-7

Lis AM, Black KM, *et al.* Association between sitting and occupational LBP. *European Spine Journal* 2007;16(2):283-98

Magnusson ML, Pope MH, *et al.* (1998) Development of a protocol for epidemiological studies of whole-body vibration and musculoskeletal disorders of the back. *J Sound Vibration* 215:643-651

Marras WS. (2005) The future of research in understanding and controlling work-related low back disorders. *Ergonomics* 15;48:464-77.

Neumann WP, Wells RP, *et al.* (1999) Comparison of four peak spinal loading exposure measurement methods and their association with low-back pain. *Scand J Work Environ Health* 25:404-9

Sarti MA, Lison JF, *et al*. Response of the flexion-relaxation phenomenon relative to the lumbar motion to load and speed. *Spine* 2001;26(18):E421-6

Solomonow M, Baratta RV, *et al*. Flexion-relaxation response to static lumbar flexion in males and females. *Clinical Biomechanics* 2003;18(4):273-9

Spielholz P, Silverstein B, *et al*. (2001) Comparison of self-report, video observation and direct measurement methods for upper extremity musculoskeletal disorder physical risk factors. *Ergonomics* 44:588-613

van der Beek AJ, Frings-Dresen MH. (1998) Assessment of mechanical exposure in ergonomic epidemiology. *Occup Environ Med* 55(5):291-9

Wells R, Moore A, *et al*. (1994) Assessment of risk factors for development of work-related musculoskeletal disorders (RSI). *Appl Ergon* 25; 157-164

Wells R, Norman R, *et al*. (1997) Assessment of physical work load in epidemiologic studies: common measurement metrics for exposure assessment. *Ergonomics* 40(1):51-61

Wiktorin C, Vingard E, *et al*. (1999) Interview versus questionnaire for assessing physical loads in the population-based MUSIC-Norrtalje Study. *Am J Ind Med* 35:441-55

WorkSafeBC. Annual Report: Statistical Supplement. 2005 Available at http://www.worksafebc.com/publications/reports/statistics_reports/assets/pdf/stats2005.pdf. (Accessed October 22, 2006)

Appendix A "Back-EST" Observation Form

Date |_2_|_0__|_0__|_5__| |___|___| |___|___| Subject ID |____|____|____|____| |____|____|____| CATHERINE / YAT / JAMES   Sheet # |____|____|____|

Observation Time															
TASK / ACTIVITY															
ITEM in Hands															
ITEM Worn															
Powered Hand Tool (**I**DLING or **O**N)															
POSTURE **S**tand; **W**alk; s**I**t; Crouch/**K**neel/Squat; **L**ay; **C**limb; **O**ther															
Trunk **0**-10⁰; **1**0-20; **2**0-45⁰; **4**5-60⁰; >**6**0⁰; **E**xtension															
Trunk is supported (1)															
Lateral Bend >20⁰ (1)															
Twisting/Rotating >20⁰ (1)															
MMH **L**ift; l**O**wer; **H**old; **P**ush; p**U**ll															
Horizontal location **N**ear; **M**id; **E**xtended															
1 Hand; **2** Hand on the item															
Weight Estimate <l lbs (**0**); 1-**1**0lbs; 10-**2**2lbs; 22-**4**4lbs; >44lbs (**5**)															
Force Estimate, Exertion **L**ight; **M**oderate; **H**eavy															
VEHICLE															
Slope **U**phill; **D**ownhill; **F**lat															
TERRAIN Smooth pave/**C**ement; **B**roken pave/cement; **G**ravel; **P**acked earth; **S**oft earth; **O**ff road **W**ater; **R**ail; **A**ir															
SPEED **I**dle/station; <**2**0km/hr; **2**0-40km/hr; **4**0-70km/hr; **7**0km/hr															
STYLE **S**mooth; **J**erky															
VEHICLE **L**oaded; **U**nloaded															
COMMENTS															

Appendix B Vehicle Form

FORM 3 – Vehicle Information

Date (year, month, day) |___|___|___|___| |___|___| |___|___|

Subject ID |___|___|___|___| |___|___|___|

VEHICLE |___|___|

TYPE ______________________________

MAKE ______________________________

MODEL ______________________________

YEAR |___|___|___|___|

GROSS VEHICLE WEIGHT (Kg) |___|___|___|___|___|

NUMBER OF AXLES |___|

POWER STEERING (Yes, No) |___|

SUSPENSION (Yes, No) |___|

TOTAL NUMBER OF OPERATION HOURS |___|___|___|___|___|___|

HOW OFTEN IS THIS VEHICLE SERVICED? (times/year) |___|___|___|

VEHICLE DESCRIPTION/PURPOSE

____

____

____

____

How OFTEN is this vehicle used? (Hrs/day) |___|___|

When is vehicle in use? (Time A to Time B) |___|___|:|___|___|

|___|___|:|___|___|

TIRE

WHEEL RADIUS (cm) |___|___|___|___|

TIRE TYPE (Wheel, Track) |___|

TIRE TREAD (sLlick/Smooth, Heavy Lug) |___|

TIRE PRESSURE WITHIN NORMAL RANGE (Yes, No) |___|

GEAR/TRANSMISSION

TRANSMISSION (Manual, Automatic) |___|

NUMBER OF GEARS |___|___|

SUPPORTS

CUSHION type (**N**one, **U**pholstered, **H**ard plastic, **R**ubber, **O**ther) |___|

If OTHER, please specify ________________

ADDITIONAL seat cushion (**Y**es, **N**o) |___|

Seat SUSPENSION (**N**one, **M**echanical, **A**ir, **H**ydraulic, **O**ther) |___|

If OTHER, please specify ________________

Seat HEIGHT from floor (cm) |___|___|___|

ARM RESTS (**Y**es, **N**o) |___|

BACK REST (**Y**es, **N**o) |___|

ADDITIONAL back support (**Y**es, **N**o) |___|

ADDITIONAL foot rest besides the floor (**Y**es, **N**o) |___|

CAB LOCATION IN RELATION TO LOAD (**A**nterior, **P**osterior) |___|

Picture taken of ENTIRE VEHICLE (**Y**es, **N**o) |___|

Picture filename ________________________________

Picture taken of TIRE (**Y**es, **N**o) |___|

Picture filename ________________________________

Picture taken of SEAT AREA (**Y**es, **N**o) |___|

Picture filename ________________________________

COMMENTS:

____

____

____

____

____

____

Appendix C Questionnaire

University of British Columbia
Back Study

PART A PARTICIPANT INFORMATION

1. **O MALE** **O FEMALE**

2. **HEIGHT** (feet, inches)

3. **WEIGHT** (pounds)

4. **DATE OF BIRTH** (Year/Month/Day)

5. **COMPANY NAME**

6. **INDUSTRY**
   - O Construction
   - O Forestry
   - O Warehousing
   - O Wood Products
   - O Transportation

7. **CURRENT JOB TITLE**

8. **CURRENT DEPARTMENT**

9. **WORKING HOURS THIS WEEK** (Hours/Day; Days/Week)

10. **NUMBER OF CONSECUTIVE DAYS WORKED INCLUDING TODAY**

11. **TOTAL COMMUTING TIME TO AND FROM WORK TODAY** (Minutes)

12. **MAIN TASKS TODAY** / **PROPORTION OF DAY (%)**

MAIN TASKS TODAY	PROPORTION OF DAY (%)
Task A. ________________________________	A1. ______________
Task B. ________________________________	B1. ______________
Task C. ________________________________	C1. ______________
Task D. ________________________________	D1. ______________
Task E. ________________________________	E1. ______________

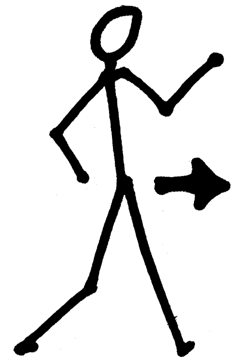
PART B   MOBILITY

13. Today while working, did you do any of the FOLLOWING? If yes, how LONG?

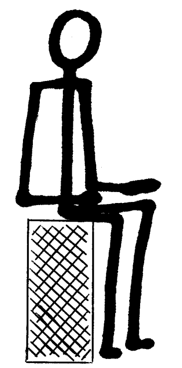
A. None
B. < 5 min
C. > 5 to < 15 min
D. > 15 to < 30 min
E. > 30 to < 45 min
F. > 45 to < 1 hr

G. > 1 to < 2 hrs
H. > 2 to < 4 hrs
I. > 4 to < 6 hrs
J. > 6 to < 8 hrs
K. > 8 hrs

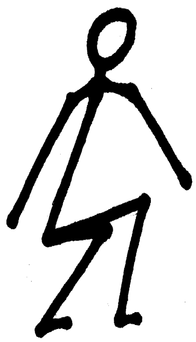
Stand



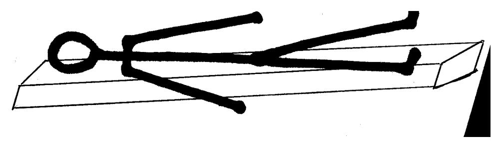
Walk



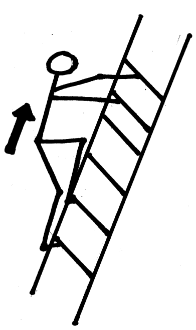
Sit



Crouch/Kneel



Lay down



Climb
(Example: stairs, ladders, scaffolds)

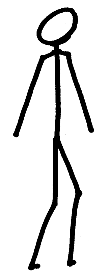
Other Activities - Not on this list

STANDING

14. Today of the time you were standing while working, did you stand with your back in the following POSTURES? If yes, how LONG?

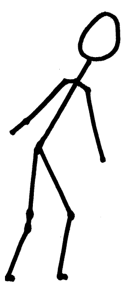
- ○ A. None
- ○ B. < 5 min
- ○ C. > 5 to < 15 min
- ○ D. > 15 to < 30 min
- ○ E. > 30 to < 45 min
- ○ F. > 45 to < 1 hr

- ○ G. > 1 to < 2 hrs
- ○ H. > 2 to < 4 hrs
- ○ I. > 4 to < 6 hrs
- ○ J. > 6 to < 8 hrs
- ○ K. > 8 hrs

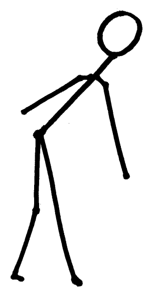


(0-10º)
Upright

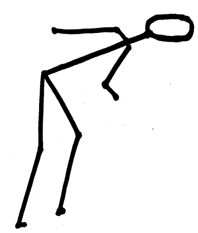
(10-20º)
Barely bent



(20-45º)
Slightly bent

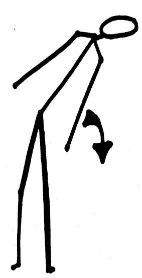


(45-60º)
Moderately bent

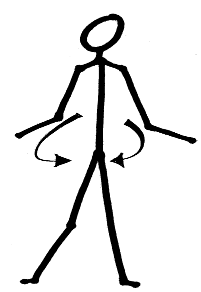


(More than 60º)
Severely bent

Bending backwards



Bending sideways



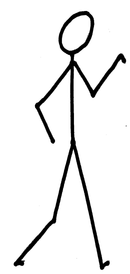
Twisting

WALKING

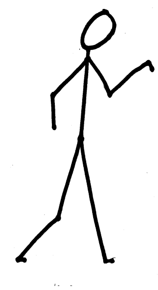
15. Today of the time you were walking while working, did you walk with your back in the following POSTURES? If yes, how LONG?

A. None
B. < 5 min
C. 5 to < 15 min
D. 15 to < 30 min
E. 30 to < 45 min
F. 45 to < 1 hr

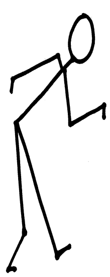
G. 1 to < 2 hrs
H. 2 to < 4 hrs
I. 4 to < 6 hrs
J. 6 to < 8 hrs
K. 8 hrs



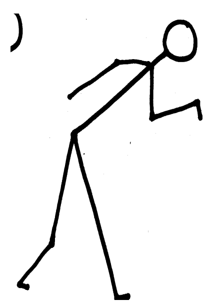
(0-10º)
Upright



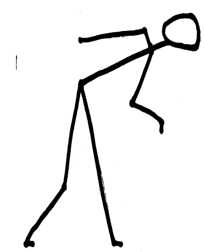
(10-20º)
Barely bent



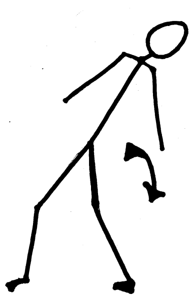
(20-45º)
Slightly bent



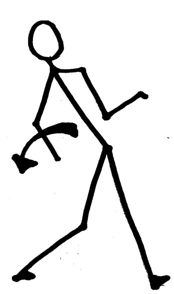
(45-60º)
Moderately bent



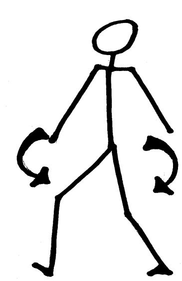
(More than 60º)
Severely bent



Bending backwards



Bending sideways



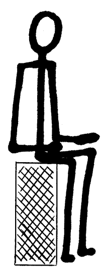
Twisting

SITTING

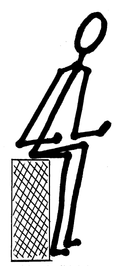
16. Today of the time you were sitting while working, did you sit with your back in the following POSTURES? If yes, how LONG?

A. None
B. < 5 min
C. > 5 to < 15 min
D. > 15 to < 30 min
E. > 30 to < 45 min
F. > 45 to < 1 hr

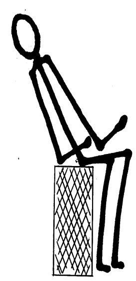
G. > 1 to < 2 hrs
H. > 2 to < 4 hrs
I. > 4 to < 6 hrs
J. > 6 to < 8 hrs
K. > 8 hrs



Upright

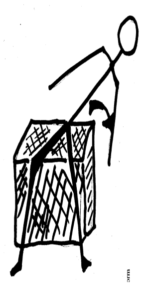


Leaning forward

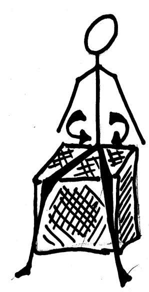


Leaning back
(with no back support)

Leaning back
(with back (support)



Bending sideways



Twisting

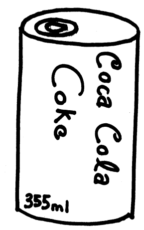
PART C MANUAL MATERIALS HANDLING

LIFTING/LOWERING/CARRYING

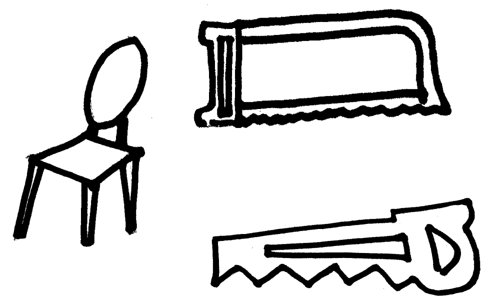
17. Today while working, did you LIFT/LOWER/CARRY any items with your hands that were ...... If yes, how LONG?

A. None
B. < 5 min
C. > 5 to < 15 min
D. > 15 to < 30 min
E. > 30 to < 45 min
F. > 45 to < 1 hr

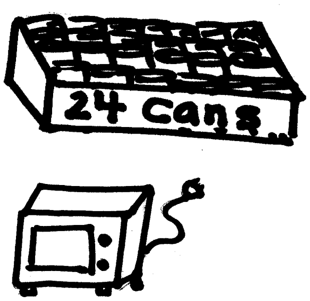
G. > 1 to < 2 hrs
H. > 2 to < 4 hrs
I. > 4 to < 6 hrs
J. > 6 to < 8 hrs
K. > 8 hrs



Less than 1 LBS

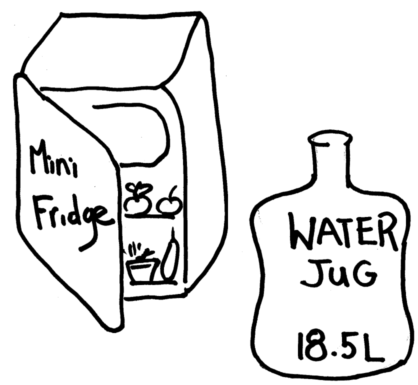


1-10 LBS



10-22 LBS

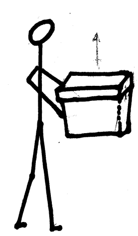
22-44 LBS

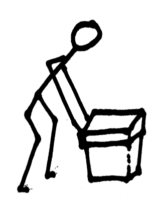


More than 44 LBS

18. Today, of the LIFTS & LOWERS you did while working, did you ...

A. Spend more time lifting
B. Spend more time lowering
C. Spend equal time lifting & lowering



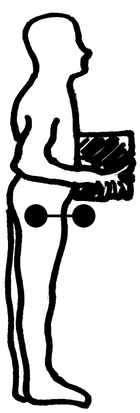


19. Today of the time you were lifting/lowering/carrying while working, how long were the loads in your hands NEAR, MID or FAR from you?

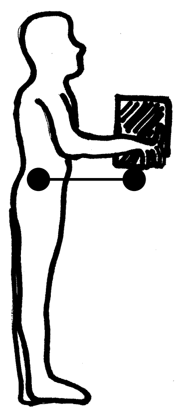
Please consider only loads that are heavier than 10 lbs.

A. None
B. < 5 min
C. > 5 to < 15 min
D. > 15 to < 30 min
E. > 30 to < 45 min
F. > 45 to < 1 hr

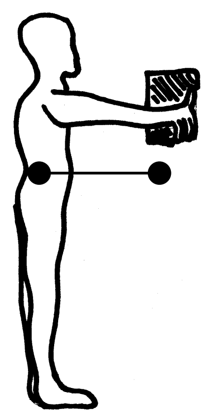
G. > 1 to < 2 hrs
H. > 2 to < 4 hrs
I. > 4 to < 6 hrs
J. > 6 to < 8 hrs
K. > 8 hrs



Near (0-10")



Mid (10-20")



Far (More than 20")

PUSHING

20. Today while working, did you PUSH any items with your hands? If yes, how LONG?

A. None
B. < 5 min
C. > 5 to < 15 min
D. > 15 to < 30 min
E. > 30 to < 45 min
F. > 45 to < 1 hr

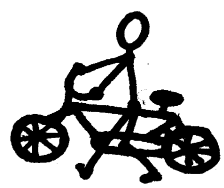
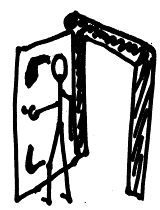
G. > 1 to < 2 hrs
H. > 2 to < 4 hrs
I. > 4 to < 6 hrs
J. > 6 to < 8 hrs
K. > 8 hrs

Examples: Push Cart, Trolley, Wheelbarrow

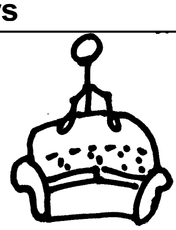
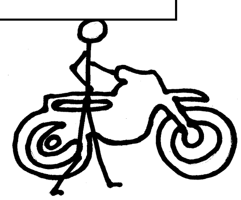
21. Today of the time you were pushing while working, how long did you push items with your hands LIGHTLY, MODERATELY, or HEAVILY?

A. None
B. < 5 min
C. > 5 to < 15 min
D. > 15 to < 30 min
E. > 30 to < 45 min
F. > 45 to < 1 hr

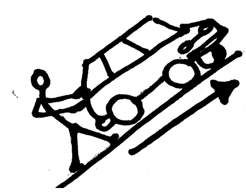
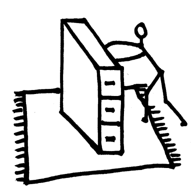
G. > 1 to < 2 hrs
H. > 2 to < 4 hrs
I. > 4 to < 6 hrs
J. > 6 to < 8 hrs
K. > 8 hrs


Light Exertion:
Small cart with files
Bicycle
Wheeled Desk Chair
Door

Moderate Exertion
Shopping cart filled with 5 40-lbs of dog food
Motorcycle
Couch

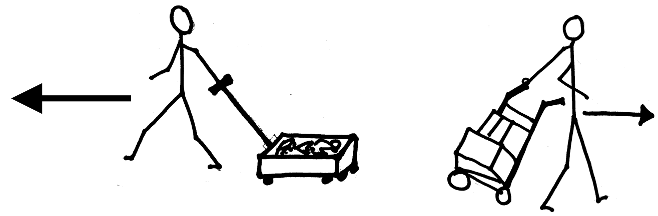
Heavy Exertion
2 or 3 drawer, full file cabinet across carpet
Piano
Car (uphill)

PULLING

22. Today while working, did you PULL any items with your hands? If yes, how LONG?

A. None
B. < 5 min
C. > 5 to < 15 min
D. > 15 to < 30 min
E. > 30 to < 45 min
F. > 45 to < 1 hr

G. > 1 to < 2 hrs
H. > 2 to < 4 hrs
I. > 4 to < 6 hrs
J. > 6 to < 8 hrs
K. > 8 hrs

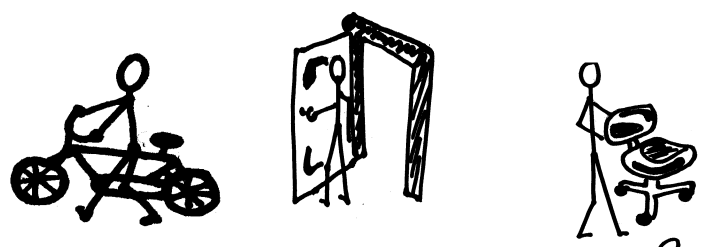


Examples: Pull Cart, Trolley, Wheelbarrow

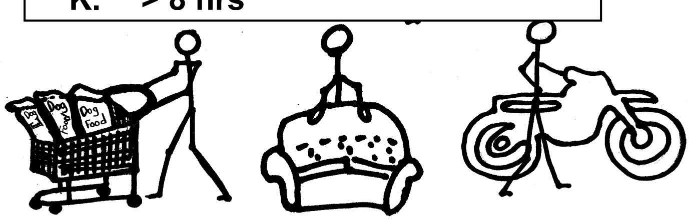
23. Today of the time you were pulling while working, how long did you pull items with your hands LIGHTLY, MODERATELY, or HEAVILY?

A. None
B. < 5 min
C. > 5 to < 15 min
D. > 15 to < 30 min
E. > 30 to < 45 min
F. > 45 to < 1 hr

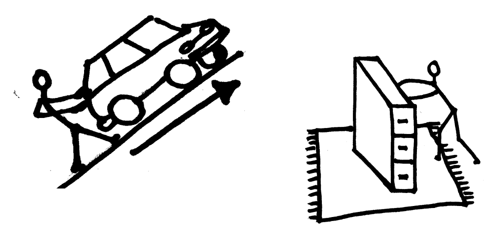
G. > 1 to < 2 hrs
H. > 2 to < 4 hrs
I. > 4 to < 6 hrs
J. > 6 to < 8 hrs
K. > 8 hrs



Light Exertion:
Small cart with files
Bicycle
Wheeled Desk Chair
Door



Moderate Exertion
Shopping cart filled with 5 40-lbs of dog food
Motorcycle
Couch



Heavy Exertion
2 or 3 drawer, full file cabinet across a carpet
Piano
Car (uphill)

PART D VIBRATION

WHOLE BODY VIBRATION

24. Today while working, did you OPERATE or RIDE any whole-body vibrating vehicle(s)/equipment? (Refer to Whole-Body Vibrating Equipment List)

a. Please NAME each vehicle/equipment.

b. Today, how LONG did you operate or ride each vehicle/equipment?

A.	None	G.	> 1 to < 2 hrs
B.	< 5 min	H.	> 2 to < 4 hrs
C.	> 5 to < 15 min	I.	> 4 to < 6 hrs
D.	> 15 to < 30 min	J.	> 6 to < 8 hrs
E.	> 30 to < 45 min	K.	> 8 hrs
F.	> 45 to < 1 hr		

c. For each vehicle/equipment, is the ARM REST adjusted for you?

YES
NO
NOT APPLICABLE because no arm rest

d. For each vehicle/ equipment, is the SEAT adjusted for you?

YES
NO
NOT APPLICABLE because no seat

e. For each vehicle/equipment, is the BACK REST adjusted for you?

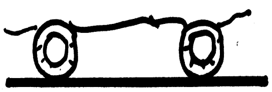
YES
NO
NOT APPLICABLE because no back rest

f. For each vehicle/equipment, does the BACK REST give you good back support?

YES
NO
NOT APPLICABLE

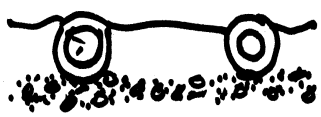
g. How long did you operate or ride each vehicle/equipment over .....

- A. None
- B. < 5 min
- C. > 5 to < 15 min
- D. > 15 to < 30 min
- E. > 30 to < 45 min
- F. > 45 to < 1 hr
- G. > 1 to < 2 hrs
- H. > 2 to < 4 hrs
- I. > 4 to < 6 hrs
- J. > 6 to < 8 hrs
- K. > 8 hrs



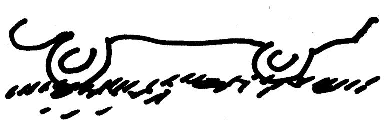
SMOOTH **pavement/cement**

BROKEN pavement/cement

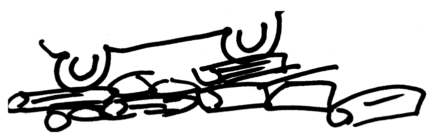


GRAVEL

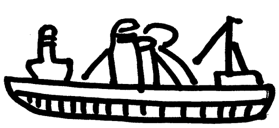
PACKED EARTH
-HARD PACKED DIRT ROAD

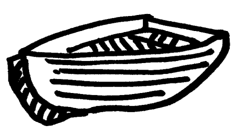


SOFT EARTH
-GRASS, SOIL



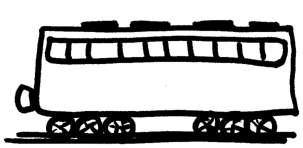
OFF-ROAD
-LOGS, ROCKS

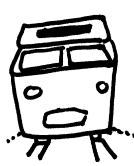




WATER
-SHIPS, BOATS

AIR
-PLANE, HELICOPTER





RAIL

h. Of the time you were operating or riding each vehicle/equipment, how long did you drive it .....

SMOOTHLY **JERKY (ACCELERATION/BRAKING)**

A. None
B. < 5 min
C. > 5 to < 15 min
D. > 15 to < 30 min
E. > 30 to < 45 min
F. > 45 to < 1 hr

G. > 1 to < 2 hrs
H. > 2 to < 4 hrs
I. > 4 to < 6 hrs
J. > 6 to < 8 hrs
K. > 8 hrs

i. Of the time you were operating or riding each vehicle/equipment, how long was the vehicle .....

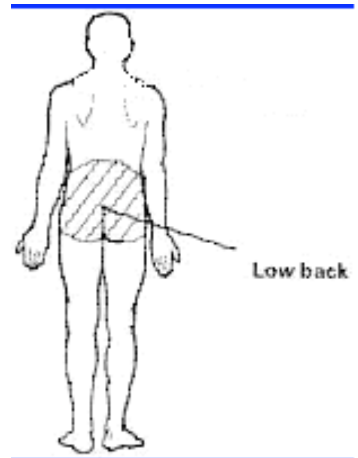
STATIONARY / IDLING
LESS THAN 20KM/HR
20-40KM/HR
40-70KM/HR
MORE THAN 70KM/HR

A. None
B. < 5 min
C. > 5 to < 15 min
D. > 15 to < 30 min
E. > 30 to < 45 min
F. > 45 to < 1 hr

G. > 1 to < 2 hrs
H. > 2 to < 4 hrs
I. > 4 to < 6 hrs
J. > 6 to < 8 hrs
K. > 8 hrs

PART E HEALTH HISTORY

25. Today, did you experience any LOW BACK PAIN?



Low back pain means aches or discomfort in the low back (shaded area) whether or not it extends from there to one or both legs (sciatica).

YES **NO (Go to question 28)**

26. TODAY, how would you rate your low back pain on a 0-10 scale, where 0 is "NO PAIN" and 10 is "PAIN AS BAD AS COULD BE"?

0 1 2 3 4 5 6 7 8 9 10

NO PAIN → **PAIN AS BAD AS COULD BE**

27. Today, did you change your usual work activities because of low back pain?

YES **NO**

↓

If yes, please explain how?

28. In the last 6 months, did you experience any LOW BACK PAIN?

Low back pain means aches or discomfort in the low back (shaded area) whether or not it extends from there to one or both legs (sciatica).

YES **NO (Go to question 35)**

29. In the past 6 months, how intense was your WORST low back pain rated on a 0-10 scale, where 0 is "NO PAIN" and 10 is "PAIN AS BAD AS COULD BE"?

0 1 2 3 4 5 6 7 8 9 10

NO PAIN → PAIN AS BAD AS COULD BE

30. In the past 6 months, ON AVERAGE, how intense was your low back pain rated on a 0-10 scale, where 0 is "NO PAIN" and 10 is "PAIN AS BAD AS COULD BE"?

(That is, your usual pain at times you were experiencing pain).

0 1 2 3 4 5 6 7 8 9 10

NO PAIN → PAIN AS BAD AS COULD BE

31. About how many days in the last 6 months have you been kept from your usual activities (work, school or housework) because of low back pain? __________ Disability days

32. In the past 6 months, how much has low 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'?

0 1 2 3 4 5 6 7 8 9 10

NO INTERFERENCE → UNABLE TO CARRY ON ANY ACTIVITIES

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

0 1 2 3 4 5 6 7 8 9 10

NO CHANGE EXTREME CHANGE

34. In the past 6 months, how much has low back pain changed your ability to work where 0 is 'no interference' and 10 is 'extreme change'?

0 1 2 3 4 5 6 7 8 9 10

NO CHANGE EXTREME CHANGE

35. During the last 6 months, on average, how many days a week have you engaged in 30 minutes or more of exercise?

Examples:
- Walking for exercise
- Golfing
- Bicycling
- Rollerblading
- Hockey

0 1 2 3 4 5 6 7 days/week

CONCLUSION

Thank you so much for answering our questions. You have been very helpful.

1. May we contact you in the future if we wish to clarify any answers you gave in this interview? YES NO

2. Is there anything else that you think we should know about that has not been asked?

____

____

____

____

____

____

3. If you have questions about the interview or the study in the future, please feel free to contact us. The names and phone numbers of the investigators are included in the consent form I have left with you. Feel free to call collect if you are outside the lower mainland.

COMMENTS:

____

____

____

____

____

____

FORM 9 – Interview Record Sheet

-The last thing we ask from you today is a questionnaire in an interview style. It will take approximately 30minutes.
-We will be asking you the questions but you can follow along with us using this interview package. This interview will ask about your activities while working today and there will be some questions about your health history.
-Some of the questions we ask may not apply to you, but it is important that we ask all our participants the same questions. We ask that you attempt to answers all the questions honestly. If you feel uncomfortable with a question, please do not hesitate to tell us so we can skip to the next question.

-Your answers will be used for research purposes only and will be kept confidential.
-Your employer will not see your answers.

Date (year, month, day) |___|___|___|___| |___|___| |___|___|

Subject ID |___|___|___|___| |___|___|___|

CATHERINE | JAMES | YAT

PART A – PARTICIPANT INFORMATION

1. SEX (**M**ale, **F**emale) |___|
2. HEIGHT |___|___|___| **cm** |___| **feet** |___|___| **inches**
3. WEIGHT |___|___|___| **kg** |___|___|___| **lbs**
4. DOB (year, month, day) |___|___|___|___| |___|___| |___|___|
5. COMPANY NAME ______________________________
6. INDUSTRY (wood **P**roducts, **C**onstruction, **T**ransportation, **F**orestry, **W**arehousing) |___|
7. CURRENT JOB TITLE ______________________________
8. CURRENT DEPARTMENT ______________________________
9. WORKING HOURS THIS WEEK A. (**Hours/Day**) |___|___|.|___|___|
   B. (**Days/Week)** |___|
10. NUMBER OF CONSECUTIVE DAYS WORKED (INCLUDING TODAY) |___|___|
11. TOTAL COMMUTING TIME TO WORK TODAY (**Minutes**) |___|___|___|
12. MAIN TASKS TODAY (gardening example: trimming, weeding, raking)

Task A ______________________________

Duration A (% of day) |___|___|___| . |___|

Task B ______________________________

Duration B (% of day) |___|___|___| . |___|

Task C ______________________________

Duration C (% of day) |___|___|___| . |___|

Task D ______________________________

Duration D (% of day) |___|___|___| . |___|

Task E ______________________________

Duration E (% of day) |___|___|___| . |___|

PART B – MOBILITY

13. MOBILITY (Did you do any of the following & how long?)

A. STAND (A-K) |___|

B. WALK (A-K) |___|

C. SIT (A-K) |___|

D. CROUCH (A-K) |___|

E. LAY DOWN (A-K) |___|

F. CLIMB (A-K) |___|

G. OTHER ACTIVITIES – NOT ON THIS LIST (A-K) |___|

14. STANDING (Did you STAND with your BACK in the following POSTURES?)

A. UPRIGHT, 0-10degrees; (A-K) |___|

B. BARELY BENT, 10-20degrees; (A-K) |___|

C. SLIGHTLY BENT, 20-45degrees; (A-K) |___|

D. MODERATELY BENT, 45-60degree; (A-K) |___|

E. SEVERELY BENT, >60degree; (A-K) |___|

F. BENDING BACKWARDS; (A-K) |___|

G. BENDING SIDEWAYS; (A-K) |___|

H. TWISTING; (A-K) |___|

15. WALKING (Did you WALK with your BACK in the following POSTURES?)

A. UPRIGHT, 0-10degrees; (A-K) |___|

B. BARELY BENT, 10-20degrees; (A-K) |___|

C. SLIGHTLY BENT, 20-45degrees; (A-K) |___|

D. MODERATELY BENT, 45-60degree; (A-K) |___|

E. SEVERELY BENT, >60degree; (A-K) |___|

F. BENDING BACKWARDS; (A-K) |___|

G. BENDING SIDEWAYS; (A-K) |___|

H. TWISTING; (A-K) |___|

16. SITTING (Did you SIT with your BACK in the following POSTURES?)

A. UPRIGHT (A-K) |___|

B. LEANING FORWARD; (A-K) |___|

C. LEANING BACK with **NO** support; (A-K) |___|

D. LEANING BACK with support; (A-K) |___|

E. BENDING SIDEWAYS; (A-K) |___|

F. TWISTING; (A-K) |___|

PART C – MANUAL MATERIALS HANDLING
(Did you LIFT, LOWER or CARRY any items & for how long?)

17. A. <1LBS (A-K) |___|

B. 1-10LBS (A-K) |___|

C. 10-22LBS (A-K) |___|

D. 22-44LBS (A-K) |___|

E. >44LBS (A-K) |___|

18. **Lifting & lowering proportions**
A. More time Lifting
B. More time Lowering
C. Equal time Lifting & Lowering |___|

19. **(How long were the loads in your hands NEAR, MID or FAR from you?)**
A. NEAR (A-K) |___|
B. MID (A-K) |___|
C. FAR (A-K) |___|

PUSHING (Did you PUSH any items with your hands & how long?)

20. Push duration (A-K) |___|
21. A. Push LIGHT exertion (A-K) |___|
B. Push MODERATE exertion (A-K) |___|
C. Push HEAVY exertion (A-K) |___|

PULLING (Did you PULL any items with your hands & how long?)

22. Pull duration (A-K) |___|
23. A. Pull LIGHT exertion (A-K) |___|
B. Pull MODERATE exertion (A-K) |___|
C. Pull HEAVY exertion (A-K) |___|

PART D – VIBRATION
WHOLE BODY VIBRATION
(Did you OPERATE or RIDE any whole-body vibrating vehicle(s)/equipment?)
24. Whole body vibration exposure (**Y**es, **N**o) |___|

VEHICLE 1 A. NAME ______________________________

B. DURATION (A-K) |___|
C. ARM REST ADJUSTED FOR YOU (**Y**es, **N**o, not **A**pplicable) |___|
D. SEAT ADJUSTED FOR YOU (**Y**es, **N**o, not **A**pplicable) |___|
E. BACK REST ADJUSTED FOR YOU (**Y**es, **N**o, not **A**pplicable) |___|
F. GOOD BACK SUPPORT (**Y**es, **N**o, not **A**pplicable) |___|
(How long?) G1. SMOOTH PAVEMENT/CEMENT (A-K) |___|
G2. BROKEN PAVEMENT/CEMENT (A-K) |___|
G3. GRAVEL (A-K) |___|

G4. PACKED EARTH (A-K) |___|
G5. SOFT EARTH (A-K) |___|
G6. OFF-ROAD (A-K) |___|
G7. WATER (A-K) |___|
G8. AIR (A-K) |___|
G9. RAIL (A-K) |___|
H1. SMOOTHLY (A-K) |___|
H2. JERKY, acceleration/braking (A-K) |___|
(How long?) I1. STATIONARY/IDLING (A-K) |___|
I2. <20KM/HR (A-K) |___|
I3. 20-40KM/HR (A-K) |___|
I4. 40-70KM/HR (A-K) |___|
I5. >70KM/HR (A-K) |___|

VEHICLE 2 A. NAME ______________________________

B. DURATION (A-K) |___|
C. ARM REST ADJUSTED FOR YOU (**Y**es, **N**o, not **A**pplicable) |___|
D. SEAT ADJUSTED FOR YOU (**Y**es, **N**o, not **A**pplicable) |___|
E. BACK REST ADJUSTED FOR YOU (**Y**es, **N**o, not **A**pplicable) |___|
F. GOOD BACK SUPPORT (**Y**es, **N**o, not **A**pplicable) |___|
(How long?) G1. SMOOTH PAVEMENT/CEMENT (A-K) |___|
G2. BROKEN PAVEMENT/CEMENT (A-K) |___|
G3. GRAVEL (A-K) |___|
G4. PACKED EARTH (A-K) |___|
G5. SOFT EARTH (A-K) |___|
G6. OFF-ROAD (A-K) |___|
G7. WATER (A-K) |___|
G8. AIR (A-K) |___|
G9. RAIL (A-K) |___|
H1. SMOOTHLY (A-K) |___|
H2. JERKY, acceleration/braking (A-K) |___|
(How long?) I1. STATIONARY/IDLING (A-K) |___|
I2. <20KM/HR (A-K) |___|
I3. 20-40KM/HR (A-K) |___|
I4. 40-70KM/HR (A-K) |___|
I5. >70KM/HR (A-K) |___|

VEHICLE 3 A. NAME ______________________________

B. DURATION (A-K) |___|
C. ARM REST ADJUSTED FOR YOU (**Y**es, **N**o, not **A**pplicable) |___|
D. SEAT ADJUSTED FOR YOU (**Y**es, **N**o, not **A**pplicable) |___|
E. BACK REST ADJUSTED FOR YOU (**Y**es, **N**o, not **A**pplicable) |___|
F. GOOD BACK SUPPORT (**Y**es, **N**o, not **A**pplicable) |___|
(How long?) G1. SMOOTH PAVEMENT/CEMENT (A-K) |___|
G2. BROKEN PAVEMENT/CEMENT (A-K) |___|

	G3. GRAVEL (A-K)	|___|
	G4. PACKED EARTH (A-K)	|___|
	G5. SOFT EARTH (A-K)	|___|
	G6. OFF-ROAD (A-K)	|___|
	G7. WATER (A-K)	|___|
	G8. AIR (A-K)	|___|
	G9. RAIL (A-K)	|___|
	H1. SMOOTHLY (A-K)	|___|
	H2. JERKY, acceleration/braking (A-K)	|___|
(How long?)	I1. STATIONARY/IDLING (A-K)	|___|
	I2. <20KM/HR (A-K)	|___|
	I3. 20-40KM/HR (A-K)	|___|
	I4. 40-70KM/HR (A-K)	|___|
	I5. >70KM/HR (A-K)	|___|
VEHICLE 4	A. NAME	____________________
	B. DURATION (A-K)	|___|
	C. ARM REST ADJUSTED FOR YOU (**Y**es, **N**o, not **A**pplicable)	|___|
	D. SEAT ADJUSTED FOR YOU (**Y**es, **N**o, not **A**pplicable)	|___|
	E. BACK REST ADJUSTED FOR YOU (**Y**es, **N**o, not **A**pplicable)	|___|
	F. GOOD BACK SUPPORT (**Y**es, **N**o, not **A**pplicable)	|___|
(How long?)	G1. SMOOTH PAVEMENT/CEMENT (A-K)	|___|
	G2. BROKEN PAVEMENT/CEMENT (A-K)	|___|
	G3. GRAVEL (A-K)	|___|
	G4. PACKED EARTH (A-K)	|___|
	G5. SOFT EARTH (A-K)	|___|
	G6. OFF-ROAD (A-K)	|___|
	G7. WATER (A-K)	|___|
	G8. AIR (A-K)	|___|
	G9. RAIL (A-K)	|___|
	H1. SMOOTHLY (A-K)	|___|
	H2. JERKY, acceleration/braking (A-K)	|___|
(How long?)	I1. STATIONARY/IDLING (A-K)	|___|
	I2. <20KM/HR (A-K)	|___|
	I3. 20-40KM/HR (A-K)	|___|
	I4. 40-70KM/HR (A-K)	|___|
	I5. >70KM/HR (A-K)	|___|

PART E – HEALTH HISTORY

25. DID YOU EXPERIENCE ANY LOW BACK PAIN TODAY? (**Y**es, **N**o) |___|

(IF NO, SKIP TO 28)

26. RATE LOW BACK PAIN TODAY (0-10) |___|___|

27. **A.** CHANGE WORK ACTIVITIES TODAY (**Y**es, **N**o) |___|

B. IF YES, explain how ______________________________

____

____

28. EXPERIENCE ANY LOW BACK PAIN LAST 6 MONTHS (**Y**es, **N**o) |___|

29. WORST LOW BACK PAIN LAST 6 MONTHS (0-10) |___|___|

30. AVERAGE LOW BACK PAIN LAST 6 MONTHS (0-10) |___|___|

31. NUMBER OF DISABILITY DAYS IN LAST 6 MONTHS FROM USUSAL ACTIVITIES (WORK, SCHOOL OR HOUSEWORK) |___|___|___|

32. INTERFERENCE WITH DAILY ACTIVITIES (0-10) |___|___|

33. LOW BACK PAIN CHANGING RECREATIONAL ACTIVITIES (0-10) |___|___|

34. CHANGE ABILITY TO WORK (0-10) |___|___|

35. HOW MANY DAYS A WEEK OF EXERCISE (30 MIN) (0-7) |___|

CONCLUSION

1. CONTACT IN FUTURE (**Y**es, **N**o) |___|

2. OTHER THINGS TO KNOW ______________________________

____

____

____

3. COMMENTS ______________________________

____

____