From Research to Reality™

2002 Annual Report of Scientific Activity
Liberty Mutual Research Institute for Safety
Through its research program, in close collaboration with customers, universities, and researchers around the world, the Liberty Mutual Research Institute for Safety strives to accomplish its primary purpose, embodied in the Liberty Mutual Creed:

With our policyholders we are engaged in a great mutual enterprise. It is great because it seeks to prevent crippling injuries and death by removing the causes of home, highway, and work accidents. It is great because it deals in the relief of pain and sorrow and fear and loss. It is great because it works to preserve and protect the things people earn and build and own and cherish. Its true greatness will be measured by our power to help people live safer, more secure lives.
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In late 2002, the Liberty Mutual Research Center for Safety and Health changed its name to the Liberty Mutual Research Institute for Safety. On the surface, this announcement may seem insignificant. In reality, the new name both celebrates the past and launches an exciting new era for the facility, which started as a single lab in 1954, and has since grown into a world-recognized research organization.

Today, hundreds of people from around the world visit the facility each year to observe our work and participate in occupational health and safety research.

2002 was an exciting 12 months for the facility. From the release of the second annual Liberty Mutual Workplace Safety Index to a partnership with the world-renowned Tsinghua University in Beijing, China, the Institute further solidified its position as the center for original research in occupational safety and health, and into the causes, consequences and prevention of disability.

It was also the year in which the Institute laid the foundation – literally – for future growth. With its physical expansion to more than 93,000 square feet – more than double its previous size – the Institute will easily accommodate its expanding research program while providing more space for visiting scholars.

We at Liberty Mutual take great pride, not only in the contributions the Institute makes, year after year, to people’s safety and health, but in the quality of the people who work there. Of particular note was the presentation of the 2002 Ergonomics Society Otto Edholm Award to Dr. Tom Leamon, who has directed Liberty Mutual’s research program for more than a decade. This award recognizes individuals for their significant contributions to basic or applied research in ergonomics.

I want to congratulate Tom Leamon for his award, and his entire team at the Research Institute for their dedication, hard work and considerable achievements.

The Research Institute also maintains a strong international presence. By partnering with world-renowned universities and research organizations, we are able to better understand and address global safety and health issues. This year, we are pleased to add Tsinghua University in Beijing, China to our growing list of international research collaborators.

As you read this, we will have recently opened our expanded and renovated state-of-the-art facility for research, training, and laboratory analysis – another reflection of Liberty Mutual’s commitment to helping create safer workplaces at home and abroad.

Karl A. Jacobson
Senior Vice President
Our trademark, “From Research to Reality,” hit close to home this year as the Research Center was transformed into a massive construction site. Watching the demolition of three of the four original buildings and a workspace expansion from 42,570 to 93,800 square feet, our staff was confronted daily with the “reality” to which our work remains dedicated. Separated by only a half-inch of glass, it is not clear which was the bigger distraction – the large machinery or the opportunity to observe supervisors enforce safe work practices. Despite the distractions, we met our 2002 targets for peer-reviewed publications and made steady progress on our safety and return-to-work research programs.

For the second consecutive year, we produced the *Liberty Mutual Workplace Safety Index* which ranks the leading causes of workplace injuries in the United States. Judging from the increasing number of media references, the report appears to be serving its purpose of drawing attention to the real sources of workplace loss. It is our hope that the Safety Index will help industry and safety-driven organizations better allocate resources to the major sources of loss. It also continues to shape our own research program, which added several new studies this year to address slips and falls, manual materials handling, and repetitive-work injuries.

On the international front, we extended our reach by signing a research agreement with the world-renowned Tsinghua University in Beijing, China. The University’s Department of Industrial Engineering is committed to reducing the social and financial burden on Chinese enterprises through workplace safety research. We look forward to bringing their intellectual capacity into our partnership and to publishing joint research findings that will lead to safer workplaces in our respective countries and beyond.

Finally, as we prepare to celebrate our 50th anniversary in 2004, we are pleased to announce our new name – The Liberty Mutual Research Institute for Safety – a name that reflects our increased research capacities and sets the stage for the next five decades of helping people live safer, more secure lives.

Tom B. Leamon, PhD
Vice President
Director of the Liberty Mutual Research Institute for Safety

From the Director
The Center for Safety Research investigates the causes and distribution of work-related injuries using a multidisciplinary approach that draws from epidemiology, biomechanics, psychology, and other sciences. Our findings provide a scientific basis for industry safety recommendations and interventions to reduce the risk of workplace injuries.

This year, we completed several studies including, a study of muscle changes during repetitive ulnar deviation, a case-crossover investigation of traumatic hand injuries, an investigation of the precision aspects of screwdriver use, and one of a series of studies on the effects of distraction on driving performance. We also made significant progress on our slips and falls research including, a study of slip potential during ladder climbing, a field investigation of slips and falls among hospital workers, and ongoing tribological investigations to determine optimal parameters for measuring surface roughness.

Among the new studies initiated and reported on this year were, a laboratory study of powered hand tool use among experienced operators, a field study of sharps-related injuries among health care workers, and an investigation into the reliability of computeized narrative text analysis as a method of obtaining information on accident and injury causes.
Identifying the causes and distribution of occupational accidents and injuries is an essential first step toward addressing workplace safety issues. Our epidemiology researchers compile and analyze occupational injury data from internal and external sources, including field study observations, to investigate existing safety concerns and identify new ones.

We are also working to develop methodologies for extracting maximum value from narrative accident descriptions. Ultimately, our epidemiological findings and methodological developments provide a scientific basis for workplace safety recommendations and help shape research agendas both within and outside of the Institute.

2002 Workplace Safety Index

For the second year, our researchers completed and published an exclusive ranking of the leading causes of disabling workplace injuries and illnesses in the United States. The 2002 Liberty Mutual Workplace Safety Index pinpointed the 10 leading causes of injuries and illness, which accounted for 86 percent of the estimated $40.1 billion in wage and medical payments made to injured workers in 1999, the most recent year for which the necessary data was available.

To develop the 2002 Workplace Safety Index, researchers took Liberty Mutual’s 1999 workers compensation mean cost data and multiplied it by the Bureau of Labor Statistics’ injury frequency data for 1999 injuries and illnesses involving more than five lost workdays. The relative proportions of each injury/illness cause group were determined and applied to national estimates of workers compensation benefits costs compiled by the National Academy of Social Insurance, which covers a broad range of workers compensation companies.

Findings from the 2002 Workplace Safety Index closely matched the results of the 2001 Safety Index. The significance of the leading causes of workplace injuries was confirmed. “Overexertion” and “same-level falls” were again cited as the leading injury causes accounting for five or more days away from work. “Bodily reaction” (injuries resulting from bending, standing, reaching, and slipping or tripping without a fall) and “falls to a lower level” ranked third and fourth.
Our epidemiology researchers compile and analyze occupational injury data to investigate existing safety concerns and identify new ones.
in the weeks prior to the injury to the presence or absence of exposure when the injury occurred.

The pilot study results indicated that being distracted, angry, or rushed increased the risk of injury by nine, six, and three times, respectively. In addition, our findings revealed that the risk of injury increased threefold when a worker made more than one pass over the patient with a sharp instrument.

We used the pilot study results to refine our study questionnaire as well as to recruit two additional hospitals into the study.

Disabling Injuries Among Construction Workers

We completed our study of disabling occupational injuries among construction workers. Initiated in 2001, the study examined 35,790 construction industry workers compensation claims to identify the leading types and sources of disabling injuries.

Researchers also calculated the typical disability duration of specific injuries using methods previously published by Institute researchers. These methods estimate the number of disability days based on the total indemnity paid to the injured worker.

The final data analysis indicated that the average disability duration for an injured construction worker was 46 days, with a median of zero days. The most frequently occurring disabling injury conditions were:

- low back pain (15 percent),
- foreign body (in)eye injuries (8.5 percent), and
- finger lacerations (4.8 percent).

Back pain accounted for the greatest percentage of construction claim costs (21.3 percent) and disability days (25.5 percent).

The conditions with the longest disability durations were sudden-onset injuries, including fractures of the ankle (median 55 days), foot (42 days), and wrist (38 days). Same-level and elevated falls were the principal exposures for fractures of the wrist and ankle, while elevated falls and struck-by incidents accounted for the majority of foot fractures. Manual materials handling activities were most often associated with low back pain disability.

These results suggest that the most disabling injuries can be addressed by increasing primary prevention resources for slips and falls and exposures related to sudden-onset injuries and by reducing manual materials handling and other exposures associated with more gradual-onset injuries.

Narrative Text Analysis

Over the past several years, our researchers have been developing computerized methods to extract causal information from accident descriptions and other narrative text sources. Our pioneer efforts in this rapidly emerging area, known as text mining, seek to maximize our ability to gain specific injury information from narrative text sources. Ultimately, these methods can provide a tool for better understanding how workplace accidents happen and how they may be prevented.

This year we used our computerized text mining methods to classify accident narratives from the 1997 and 1998 United States National Health Interview Survey (NHIS). The annual survey, conducted by the National Center for Health Statistics (NCHS), gathers information on disease and injury distributions as well as impairment and disability. More than 100,000 people from 43,000 households take part in the survey.

Using a statistical model based on conditional probability theory, the computer identified and classified external cause of injury codes – such as motor vehicle, falls, foreign body (in) eye, or
overexertion – into 13 broad categories. To evaluate the program’s performance, we compared the computer-generated codes to the e-codes assigned by NCHS-trained experts. Our analysis indicated that:

1) The computer correctly classified 83 percent of the external codes when multiple keywords were included in the model;

2) The use of multiple-word predictors (two-, three-, and four-word combinations) improved both the sensitivity and specificity of the computer-generated codes as compared with using single-word predictors; and

3) The program has the capability of identifying and filtering out those records that cannot be coded at high confidence or threshold levels.

These results suggest that accident narratives can be e-coded by machine with reasonable accuracy when using a multiple-word classification approach. The ability to set threshold levels significantly reduces the amount of manual coding required without sacrificing accuracy. This allows the analyst to focus on difficult narratives that need to be coded manually.

Risk Factors for Traumatic Hand Injuries

We completed our case-crossover field investigation of transient risk factors for acute traumatic occupational hand injuries. This study was a long-term collaborative effort between researchers at our Institute and faculty members from the Harvard School of Public Health.

Comparison of Computer- Versus Expert-Coded Narrative Injury Text

Computer coding of narrative injury text compares favorably to expert coding when the multiple-word model is used. (N represents the number of accident narratives.)
We interviewed a total of 1,166 patients to evaluate the role of potential risk and protective factors present at the time of a work-related traumatic hand injury. The findings will be used to help promote scientific understanding of traumatic hand injury risks and to help businesses design interventions to reduce the frequency of such injuries.

For this study, researchers interviewed workers from various industries (e.g., machine trades, construction, manufacturing, and service) within two days of an injury. With cooperation from 23 occupational health clinics, we asked workers to provide information on the circumstances during the 90 minutes prior to the injury, including whether or not specified risk factors were present. Workers also provided open-ended descriptions of how their injuries occurred, as well as information on whether the same risk factors were present during the month prior to injury.

The study findings indicated that workers whose machinery, tools, or workpieces were not performing as expected (such as jammed machinery), or those who were using a different work method to perform a task, were about 11 times more likely to experience a hand injury than workers who were not exposed to these circumstances. Other factors, in decreasing order of risk, included: performing an unusual task, being distracted, and being rushed.

Further analysis indicated that more than half of the reported injuries (54.6 percent) occurred in the morning, between 9 a.m. and 12 p.m., and that the median amount of time into the work shift at the time of injury was 3.5 hours.

These results suggest the significance of certain potentially modifiable transient risk factors as contributors to occupational hand injuries. This knowledge will help in the development of industry-specific interventions to help reduce these types of injuries. Additionally, the findings related to temporal factors suggest the importance of increased vigilance during the early hours of the workday when hand injury frequency is higher.

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Publications

**Professional Safety**

Getting Answers From the BLS Data on Disabling Injuries

**American Journal of Infectious Disease Control**

Willingness to Pay to Avoid Sharps-Related Injuries: A Study on Injured Health Care Workers

**Journal of Occupational and Environmental Medicine**

Disabling Occupational Injury in the U.S. Construction Industry 1996

Acute Traumatic Occupational Hand Injuries: Type, Location, Severity
Every worker — whether in a manufacturing plant, restaurant kitchen, construction site, or office cubicle — is subject to the physical, organizational, and task-specific demands of the job at hand. Understanding these demands, especially for higher risk jobs, is vital to providing safe work solutions and effective interventions. Our researchers apply a multidisciplinary approach to study the workplace demands that occur in a variety of job situations and to assess the impact of existing interventions. This approach integrates the principles of biomechanics, ergonomics, psychophysics, and organizational sciences to provide a scientific basis for addressing job safety concerns.

**Industrial Meat Cutting**

The meat processing industry has historically reported high numbers of musculoskeletal injuries. Many of these injuries are directly related to the demands associated with meat cutting, which include force, repetition, and awkward postures. Despite the known injury risks, there is little information on the specific levels of exposures that can lead to musculoskeletal disorders.

To begin to address this, our researchers conducted a field-based ergonomic assessment of meat-cutting tasks.

We recruited nine male workers at a meat processing facility for the investigation. After collecting basic demographic and grip force data on each subject, researchers completed ergonomic assessments as workers performed three cycles of a shoulder-deboning task. An instrumented knife was used to measure and record grip forces and cutting moments during the task. Time per cycle and time per cutting task were also calculated.

The average grip force values recorded during the deboning task fell between 11 and 35 percent of the maximum voluntary grip force. The latter end of the range is considered high for a task performed during eight-hour or longer shifts. The data also indicated a high between-subject variation in exposure to integrated grip forces and cutting moments. Workers with less experience tended to require more time to complete each cycle, thus they exerted higher integrated grip forces. They also had a tendency to
use a sawing motion to complete cuts. This motion positively correlated with more and higher integrated grip forces per cycle.

In addition to the field investigation, we moved forward on a laboratory-based ergonomic evaluation of industrial meat-cutting tasks. This study examines the effects of workstation configuration, knife blade angle, pace, and task complexity on performance variables such as grip force, cutting time, and wrist posture.

Twelve male subjects completed a four-session protocol involving 72 simulated industrial meat-cutting tasks. Subjects performed cutting tasks on modeling clay in various combinations of:

- Workstation orientation (0, 30, and 60 degrees),
- Height (elbow height, elbow minus five inches, elbow minus 10 inches),
- Knife blade angles (straight versus bent),
- Pace (self- versus productivity-paced), and
- Complexity (simple versus complex task).

Each subject used an instrumented knife so that researchers could measure grip forces and cutting moments. They also wore a goniometer to measure wrist flexion and deviation.

Preliminary results showed that average cutting moments were 17 percent higher and gripping forces were 26 percent higher for productivity-paced sessions. An unexpected finding was that the cutting moment was 13 percent higher for the simple cutting condition than for the complex cutting condition. Likewise, the grip force was 11 percent higher for the simple cutting condition. This may have occurred because subjects took less time to complete the simple task, but exerted more force in order to complete the task more quickly. Researchers continue to examine the effects of workstation set-up variables and analyze the postural data collected with the wrist goniometer.

Ultimately, the results of this and related studies will provide a scientific basis for meat-cutting industry risk-reduction strategies.

Ladder Slips and Falls

Slips and falls from ladders are a major source of injury both in and out of the workplace. There are many aspects of ladder use that pose a potential danger, but little validated information on how to reduce the risk of a ladder slip or fall. Our researchers initiated a long-term investigation to identify some of the probable contributors to slips and falls from ladders. The information gained will be useful in the development of technical innovations and guidelines to help prevent ladder injuries.

This year, we conducted a laboratory study to evaluate the effects of various factors such as climbing speed, ladder angle, body weight, and type of top support (roller versus non-roller) on the friction requirement between the ladder bottom and the floor surface. Researchers used a force plate to measure the vertical and horizontal forces at the bottom of an inclined ladder (65 and 75 degrees) as subjects climbed at slow and fast rates. A total of 17 subjects, classified into three groups by body weight (light, intermediate, and heavy), performed 16 variations of the ladder climbing task. The bottom of the ladder was constrained to prevent it from moving, and subjects wore harnesses as a safety precaution.

We analyzed the force plate results to assess the friction requirements under the various climbing conditions. Preliminary results indicated...
that inclined angle and climbing speed were the most critical factors affecting the friction requirement at the bottom of the ladder. In particular, the required friction almost doubled when the ladder’s inclined angle was reduced from 75 to 65 degrees. There was also a seven percent increase in the required friction as subjects increased their climbing speed from 55 to 75 steps per minute.

**Measurement of Slipperiness**

The use of slipmeters to measure the slip resistance of shoe and floor surfaces is accepted practice both in research and in industrial safety environments. Slipmeter measurements are often used to develop floor surface selection guidelines and cleaning protocols aimed at reducing occupational slips and falls. However, different research institutions tend to report different measurements even when identical slipmeters are used on the same types of floor surfaces. To investigate this discrepancy, we began a series of tribological studies that compare measurements taken with two common industrial slipmeters: the Brungraber Mark II and the English XL.

This year, we analyzed floor surface measurements taken previously at 18 restaurants of a national fast food chain. Research technicians used both slipmeters to measure the slip resistance of floor and shoe surfaces in four selected kitchen areas: grill, fryer, back sink, and back door. At each of the 18 restaurant sites, we took 96 measurements (48 with each slipmeter) in the four selected areas for a total of 6,912 trials.

The initial data analysis revealed that on average, measurements taken with the Brungraber Mark II showed more consistent measurements than those taken with the English XL for all four kitchen areas. These results suggest that overall, the Brungraber Mark II is more sensitive to floor conditions than the English XL. The data also suggested that the common practice of hand sanding footwear samples used in the devices and the problem of grease build-up during repeated strikes may affect the measurement accuracy of both slipmeters.

**Office Ergonomics Interventions**

The dramatic increase in office technologies during the latter part of the 20th Century changed the landscape of the American workplace to include many more sedentary, keyboard-intensive jobs and job functions. As the workforce became more computer-oriented, the incidence of upper extremity disorders increased steadily among working-age adults in the United States. In an effort to address this trend, our researchers study the demands placed on occupational computer workers and measure the effects of various interventions.

As part of a field-based study examining the effectiveness of office ergonomic interventions, our researchers looked at musculoskeletal symptom reporting among office workers over a typical workday and workweek. Workers participated in online surveys one and two months prior to intervention, and then two, six, and twelve months post-intervention. The surveys asked workers to rate their levels of pain or discomfort at the beginning, middle, and end of the workday for each of the following body areas: neck, upper arm, elbows/wrists, lower back/trunk, buttocks/thighs, and lower leg/ankles/feet.

According to data collected from 200 workers of a single employer, baseline musculoskeletal symptoms increased over the course of the workday, but did not increase over the workweek. This finding suggests that, on average, workers recover from their symptoms overnight, then experience the same increase in symptoms the next workday. This group of workers also reported lower overall levels of symptom severity in the second pre-intervention questionnaires, as compared to the first. While this finding may point
to the effects of the interventions, additional data from other organizations is needed to validate this observation.

**Utility Cover Lifting**

Overexertion remains the leading cause of workplace injury in the United States, accounting for more than $10 billion in annual direct costs to employers. The injuries resulting from overexertion are most often the result of excessive lifting, lowering, pushing, or pulling of an object. Over the past several years, the telecommunications industry has seen a growing number of overexertion injuries, primarily among field technicians who lift heavy utility covers to access underground telephone and cable lines.

This year, we completed an ergonomic investigation of utility cover lifting tasks. The purpose of the study was to obtain scientific information on the biomechanical and physical demands associated with these tasks, as well as to assess the usability, effectiveness, and maneuverability of eight different cover lifting tools. The information gained will be used to help address the high number of musculoskeletal injuries among workers who perform these tasks.

Using state-of-the-art motion tracking equipment, we collected anthropometric and postural movement data as experienced field technicians performed utility cover lifts. The workers were given eight different tools to perform the tasks; five of the tools had a simple J-hook configuration, two

![Utility Cover Lifting Tool Comparison](image)

In a comparison of eight different utility cover lifting tools, the fulcrum bar tools produced the smallest lower back compressive forces. (A-E indicates statistical grouping.)
Our researchers initiated a new laboratory-based study to compare the effects of reaction force on experienced and novice powered hand tool users.
Publications

**Ergonomics**

Usability of the Revised NIOSH Equation

**Safety Science**

The Effects of Slip Criterion and Time on Friction Measurements

The Effect of Gait Speed and Load on the Reliability of Ground Reaction Forces

**Work**

Effects of a Participatory Ergonomics Computer Workshop for University Students: A Pilot Intervention to Prevent Disability in Tomorrow’s Workers
For nearly half a century the Research Institute has investigated human capacities and limitations for performing common work tasks. By simulating industrial tasks in the laboratory and applying psychophysical methodologies, our researchers determine maximum acceptable workloads for manual materials handling tasks and upper extremity repetitive motions. More recently, we have expanded the scope of our human capacities research to include biomechanical analyses of simulated industrial tasks and cognitive studies to examine decision-making processes and safety perceptions among workers. This multidisciplinary approach increases our understanding of the physical and psychological factors that can impact worker safety and on-the-job performance.

**Cognitive Studies**

Our cognitive research investigates how such factors as human perception, mental workload, decision making, working memory and other cognitive factors impact workplace safety. We are currently conducting studies concerned with the ability to distribute attention and mental resources across multiple tasks (i.e., driving and cell-phone use) and the resulting limitations in performance. We are also examining human awareness of performance decrements in simulated work situations.

**Driver Distraction Research**

We continued our data analysis of a year 2000 study that focused on how various distractions affect driver performance. This year’s analysis involved determining the extent to which drivers are aware of performance issues when distracted. We also examined drivers’ relative ability to compensate for any performance issues. Our research in this area aims to advance our understanding of the relationship among in-vehicle technologies, various driving situations, and different driver characteristics to ultimately enhance safety on the roads.

In a prior study, we found that the driving performance of older drivers and female drivers when handling a cell phone distractor suffered more than that of younger drivers and male drivers. This year, we examined the extent to which drivers’ perceptions of their ability to deal with distractions while driving accurately reflected driving performance in the presence of a cell phone task. We employed three different approaches to examine the
relationship between driver confidence in dealing with distractions and actual driving performance.

Our findings suggest that while high confidence ratings appear to predict better driving performance for male drivers - the more confident the driver, the less hindered he was by the distraction - the relationship did not hold to the same extent for females. When drivers were matched on confidence level, older females showed the greatest slowing in brake response times in the presence of distraction. Females also rated the driving task as less demanding than the males, even though their performance suffered more when distracted. Our findings suggest that educational campaigns on driver distraction could be effectively targeted toward female drivers.

**Upper Extremity Repetitive Motions**

We continued our investigations of simulated industrial tasks requiring repetitive upper extremity motions. Using a psychophysical methodology, our researchers gather and analyze data on maximum acceptable torques as subjects perform tasks involving the hands, wrists, and/or arms. We use our findings to establish maximum acceptable workloads for comparable industrial tasks. This information is then compiled and incorporated into our patented task analysis software program for use in actual industry settings.

**Supination and Pronation**

This year we completed a study of the hand and wrist motions - namely, supination (clockwise motion) and pronation (counter-clockwise motion) - used to perform industrial screwdriving tasks. During the four-week data collection phase, 10 subjects performed simulated screwdriving tasks seven hours a day at either 15, 20, or 25 repetitions per minute, under four conditions: supination with a 31 mm handle, a 40 mm handle, and a 39 mm yoke handle; and pronation with a 31 mm handle.

We also looked at tasks involving ulnar deviation with a power grip (comparable to industrial knife cutting) and a hand grip task (similar to using pliers). For each session, subjects adjusted the resistance on the handle to what they perceived to be an acceptable level. Subjects were instructed to work as hard as they could without developing unusual hand, wrist, or forearm discomfort and were asked to record their symptoms during the last five minutes of each hour.

Analysis of the data indicated that for the screwdriving tasks involving supination, the mean maximum acceptable torque ranged from 0.33 Newton meters (Nm) to 0.65 Nm. For the task involving pronation, the mean maximum acceptable torque ranged from 0.38 Nm to 0.47 Nm. For the remaining ulnar deviation and handgrip tasks, the mean maximum acceptable torques ranged from 1.08 Nm to 1.13 Nm and from 4.80 Nm to 4.85 Nm, respectively. These values represent 14 to 24 percent (median 17 percent) of maximum isometric torque, depending on the frequency and motion. Using the information gained, we developed a table of maximum acceptable torques and forces of each of the studied motions for application in the field.

**Precision Aspects of Screwdriver Use**

We completed a study of the effects of work height, workpiece orientation, gender, and screwdriver type (Phillips or flat head) on productivity and wrist deviation during a repetitive screwdriving task. The information gained from this and related studies will be used to develop recommendations to enhance workplace safety, health, and performance.

Seven males (mean age 37.6) and seven females (mean age 51.7) were recruited for the experiment. Following a training session, each...
subject participated in two data collection sessions. Each session comprised 45 screwdriving task variations involving:

- two screwdriver designs (Phillips and flat head);
- five work heights (elbow height, elbow height plus and minus five inches, elbow height plus and minus 10 inches); and
- nine workpiece orientations in the sagittal plane (-60, -45, -30, -15, 0, 15, 30, 45, and 60 degrees).

Each condition consisted of two one-minute replications followed by a two-minute rest period. Each subject wore a wrist goniometer throughout the sessions to enable researchers to collect data on wrist deviation in two planes (radial/ulnar deviation and flexion/extension). Subjects were also asked which screwdriver they would prefer if the experimental task were their full-time job, and the reasons for their choice.

An analysis of the data revealed that both males and females performed better with the Phillips head screwdriver. Although gender was not significant, the interaction between gender and screwdriver was significant, with females having a greater performance difference (30%) between the two screwdriver designs than males (10%). There were also strong interactive effects of workpiece orientation and work height on productivity and measures of wrist deviation.

The results of this study indicate that the relationships between workplace design, productivity, and wrist deviation are interactive. This finding reiterates the importance of good ergonomic design as a way to effectively enhance productivity and minimize stress.

**Repetitive Ulnar Deviation Tasks**

We also completed one of our investigations of repetitive motions involving ulnar deviation (a sideways wrist movement common to industrial tasks such as meat cutting or hammering). The study, a joint effort with the Harvard School of Public Health, measured EMG changes in the extensor carpi ulnaris (forearm) muscle as subjects performed a repetitive ulnar deviation task. Electrical stimulation was also used to quantify the mechanical changes resulting from muscle activity.

Using psychophysical workloads determined in the first phase of the experiment, 13 female workers performed a simulated industrial task involving ulnar deviation for two eight-hour days under each of three conditions: a control period with no repetitive ulnar deviation activity, 20 repetitions per minute, and 25 repetitions per minute.

Eight times during both the work and control days, researchers took EMG measurements of the extensor carpi ulnaris muscle during isometric contractions of 20 and 60 percent of maximum voluntary contraction.

The data analysis indicated that the EMG signal amplitude was lower on workdays as compared to control days. Although power was reduced in all spectrum bands of the EMG power spectra, the reductions were not uniform across the entire frequency range. The initial median EMG signal frequency showed no change between the control and workdays. However, over the course of eight hours, the decline of the median frequency during each isometric contraction became steeper during the workdays as compared to control days. These changes suggest that the muscles are in an early stage of fatigue after an eight-hour workday.

Each time the researchers performed EMG measurements, they also applied electrical stimulation of 2, 20, and 50 hertz to subjects’ extensor carpi ulnaris muscle in order to measure the mechanical response. In addition, subjects were asked to record their perceived arm fatigue at various points during the day.

According to the data, the muscle’s mechanical response to electrical
stimulation was fairly constant in the control condition. However, in the repetitive work conditions, we observed muscle potentiation—a first-stage protective mechanism to counteract fatigue—at all frequencies. The amount of potentiation increased as the frequency of electrical stimulation increased. These results suggest that at psychophysically determined workloads, the extensor carpi ulnaris muscles manifested early stages of fatigue over the eight-hour work session, even though subjects did not report any substantial discomfort or fatigue. These indicators, which were unperceived by subjects, returned to baseline before the next work session.

The third objective of the study was to see if we could detect any low-frequency fatigue (LFF) during the work phase. LFF is measured by the ratio of force output from low-frequency (20 Hz) and high-frequency (50 Hz) stimulation. The results did show significant decreases in the ratio of the extensor carpi ulnaris tetanus force produced by the repetitive work, indicating that some LFF had occurred.

Biomechanical Modeling

A common approach to understanding human systems is to try to formulate individual physical capacities and behaviors mathematically, fit the parameters of the mathematical model to the experimental results, and then study the generalization of the model. This interactive process can clarify the features of the work system, teach us more about the system, and suggest new experimental approaches. Through human performance modeling in the workplace it is possible to test the knowledge, reliability, and human limitations in order to develop appropriate interventions.

Glenohumeral Joint Research

We continued our long-term investigation of individual geometrical differences in the glenohumeral (shoulder) joint, and the impact of such differences on individual load limitations. By calculating individual workloads from magnetic resonance imaging (MRI) information and comparing them to data gathered from subjects as they perform simulated industrial tasks, we seek to determine whether the theoretical calculations correspond to the laboratory findings. Ultimately, our findings will provide the basis for a biomechanical model of the glenohumeral joint, which will aid in injury prevention, diagnosis and rehabilitation efforts, and the development of safer work standards.

This year, we compiled MRI data previously collected from 12 subjects who had never experienced chronic shoulder pain, stress fracture, or joint injury. The data included information and measurements of bone surfaces, ligament lengths, joint looseness, and contact surfaces. This information was used to calculate the maximum acceptable workload that could be applied to the hand without injuring the glenohumeral joint. We did these calculations for each of the 12 subjects, taking into account individual geometries and mechanical strength.

Once the workloads were theoretically determined, we asked the same 12 subjects to perform a series of simulated industrial pushing and pulling tasks. Over a two-week period, each subject performed two and four repetitions of constraint range upper-limb abduction (pushing) and adduction (pulling) at six different angles (5, 10, 15, 20, 25, and 30 degrees) while standing. For each repetition, participants were instructed to gradually increase their effort to what they felt was an acceptable maximum force. Once the maximum force was reached, subjects applied that force to an instrumented bar for two seconds and then held the force constant for three seconds as researchers measured the maximum voluntary contraction. The total testing time including set-up and rest breaks was approximately 20 minutes per day.
A preliminary analysis of the MRI and simulated task data indicated that the maximum weight a subject was able to pull was related to geometry of the joint and arm position as well as handle position. The data also indicated that when individuals performed a pushing task, the bone-on-bone forces have the greatest influence on the maximum acceptable workload, and the load applied at the hand is a critical element for assessing individual forces during activities.

We also compared the laboratory findings to the maximum acceptable workloads calculated from the data on their individual MRIs. We observed that: four subjects performed above their theoretically calculated maximum acceptable workload, four subjects performed tasks at their theoretically calculated maximum acceptable workload, and four subjects performed tasks below their theoretically calculated maximum acceptable workload.

**Manual Materials Handling**

Manual materials handling tasks, such as lifting, pushing, pulling and carrying objects continue to be a leading source of workplace injuries. In the 1970s, our researchers began a series of manual materials handling studies to determine maximum acceptable workloads for female industrial workers. We have used the findings from these studies to enhance our computer-based task analysis software (CompuTaskTM) and to better address the needs of today’s diverse work populations.

**Maximum Acceptable Forces for Females**

In a recent experiment, we had 11 female industrial workers perform pushing tasks using both a magnetic particle braked treadmill and a high momentum pushcart. The purpose of the experiment was to investigate maximum acceptable forces as subjects performed a 25-foot push at a frequency of one push per minute using the two testing systems. Our researchers collected data as the subjects performed three two-hour pushcart tasks and one 40-minute treadmill pushing task. These tasks were performed in the context of a larger experiment involving three days of training followed by 17 four-hour days. A psychophysical methodology was employed whereby the subjects were asked to select a workload they could sustain for eight hours without straining or becoming unusually tired, weakened, overheated, or out of breath.

A preliminary analysis of the data indicated that the female subjects responded similarly to male subjects in a comparison of the maximum acceptable forces of pushing on the treadmill versus the high momentum pushcart. However, the magnitude of difference was not the same. We found that the maximum acceptable force was 23 percent higher on the pushcart than on the treadmill for male subjects, and 14 percent higher for female subjects.

In a part of the experiment dealing with floor slipperiness, we found that the women had a 28 percent lower maximum acceptable force on a low-friction floor than on a high-friction floor. For men the same measurement was 38 percent lower. In addition, the men experienced considerably more slipping than the women when performing pushing tasks on the lower-friction floor.
Publications

**Ergonomics**

Psychophysical Study of Six Hand Movements

**Applied Ergonomics**

A System for the Measurement of Grip Forces and Applied Moments During Hand Tool Use

**International Journal of Industrial Ergonomics**

The Effect of Box Size, Vertical Distance, and Height on Lowering Tasks

Maximum Acceptable Horizontal and Vertical Forces of Dynamic Pushing on High and Low Coefficient of Friction Floors
Researchers at the Center for Disability Research study factors that predict or influence return-to-work outcomes and investigate ways of improving these outcomes. While our research focuses on various aspects of occupational disability, the goal of each project is the same – to improve the quality of life for all workers by helping them return to safe, sustained employment after an injury.

Our researchers initiated several new studies in 2002. We explored primary care provider involvement in work-related back pain, and analyzed spinal cord injury treatments. We also began a comparison study of alternate approaches to treating carpal tunnel syndrome, and investigated the impact of chiropractic care on return-to-work outcomes. Another study focused on whether electromyographic activity can be used to direct low back pain treatment.

In addition to these new projects, our researchers completed a study of Intradiscal Electrothermal Therapy outcomes for low back pain patients, and looked at new ways to measure the success of vocational rehabilitation programs. We also continued investigations on the impact of supervisor training on return-to-work outcomes, contributing factors to low back reinjury and the unique return to work issues facing older workers – one of the fastest growing segments of the United States work population.
Lost work time due to occupational disability accounts for more than $350 billion in annual costs to employers and workers. Studies have shown that nearly half of these costs could be avoided with optimal medical management, disability prevention, and workplace accommodation strategies. We study existing clinical treatments and case management approaches to reducing disability in an effort to find the best ways to help disabled workers regain health and job function. Our research is aimed at providing a scientific basis for improving return-to-work outcomes.

Intradiscal Electrothermal Therapy Outcomes

As part of our efforts to investigate and evaluate the impact of new treatments on return-to-work outcomes, we completed a study of Intradiscal Electrothermal Therapy (IDET). This procedure, which has been implemented to treat patients with discogenic low back pain, uses a heated probe to destroy pain receptors thought to be the source of discomfort.

We completed our analysis of data from 142 cases of workers who had received IDET treatment with a minimum of two years of follow-up. An examination of return-to-work outcomes indicated that only a small group of patients actually improved their work status as a result of the treatment. Overall, 37 percent of all cases were working at 24 months post-IDET. However, within this subset, nearly half had already been working prior to receiving the treatment. Additionally, a significant number who had been working pre-IDET were not working one year after treatment.

Initial published reports suggested that post-IDET surgeries or injection treatments are required in less than 11 percent of cases. In our study, however, more than a third of those who had been treated with IDET required epidural injections and/or further surgery to manage their pain. More than half of the treated patients required continued narcotic use six months or more post-IDET.

The strongest indicators of poor outcomes post-IDET (such as prolonged disability, requirement for additional invasive pain management interventions, and continued prescribed narcotic use) included
being self-referred (the same provider performed both the pre-IDET diagnostic and the IDET procedure), having a litigated case, and use of narcotics during the three months pre-IDET.

Carpal Tunnel Surgery Treatment Outcomes

We completed the pilot study data analysis for an outcomes investigation of two surgical approaches to treating work-related carpal tunnel injuries – endoscopic and open-hand carpal tunnel release. The goal of the study is to develop an economic model to compare the return-to-work results and post-surgical costs associated with the approaches. This model could help improve return-to-work outcomes and decrease workers compensation costs through better treatment and intervention selection. Once it has been validated, the model may be applied to evaluate other occupational injuries and treatments.

The initial data extraction yielded 6,000 carpal tunnel claims that involved a surgery after January 1, 1995. Each claim had at least 12 months of post-surgery follow-up. A preliminary analysis of the data from this study period indicated that open-hand surgeries outnumbered endoscopic carpal tunnel release procedures by a ratio of five to one. Direct surgical costs were found to be higher for endoscopic procedures, while the average length of disability was shorter. The data also revealed that attorney involvement was more frequent in claims involving endoscopic surgery.

Our researchers also began extracting outcomes information, including length of disability, nature of the return-to-work outcome, total medical and indemnity costs, length and type of treatments before and after surgery, age, occupation, attorney involvement, average weekly wage, and time span between injury and surgery. This data will be analyzed to identify significant influences on return-to-work outcomes.

Impact of Chiropractic Care on Return to Work

Physical medicine treatments (including chiropractic treatments) represent more than a quarter of all medical costs in the workers compensation system. However, there is little scientific evidence to support an ideal approach for applying these treatments to achieve optimal return-to-work outcomes.

In collaboration with the Occupational Health Program at the Harvard School of Public Health, we are studying the relationship between the level of chiropractic services use and return to work, while controlling for factors that may influence outcomes, such as age, gender, occupation, and nature and severity of injury. We are also examining whether high versus low use of chiropractic care can be linked to prolonged work absences, recurrences, or extension of overall medical treatment.

The study examines occupational low back pain injuries with at least one visit to a chiropractor that occurred between January 1, 1995, and December 31, 2001, in selected workers compensation jurisdictions. By analyzing the frequency of chiropractic care on a state-by-state basis, we are able to classify these jurisdictions based on the use of chiropractic benefits, comparison of chiropractic care use with known state policies regarding the entitlement to such care, and the existence of any shifts in chiropractic entitlement during the study period.

We are focusing on those states where shifts in entitlement occurred to evaluate the impact of such changes on return-to-work outcomes. We have identified four possible levels of chiropractic care use, ranging from no chiropractic

We study existing clinical treatments and case management approaches to find the best ways to help disabled workers regain health and job function.
care to using a chiropractor as the primary care provider and are controlling for these levels of use in the study.

The initial findings confirmed that there is a significant variation in average jurisdictional utilization of chiropractic care in the course of treatment of occupational low back pain. Similar differences were observed when we considered the share of individuals utilizing chiropractic care in the total number of claimants with occupational low back pain. We began the process of identifying the likely causes of these differences and reasons for changes in utilization within a particular jurisdiction during the study period.

**Objective Versus Subjective Work Performance Measures**

Insights on how health affects work performance can provide guidance for preventive and treatment interventions to benefit workers and their employers. However, work performance measures are often complicated and difficult to relate to actual at-work performance. Objective work performance measurements can be complex, multifaceted, and challenging to analyze. Self-reported measures, while easier to obtain and analyze, are unreliable in their relationship to actual at-work performance.

To address these issues, we began a study to look at the relationship between objective and subjective measures of work performance. The goal is to improve our understanding of how these types of measures can be used together to determine how health status and illness affect work ability.

We studied 124 employees working at three sites of a medical bill review and approval operation. Our subjects were working full-time, had been on the job at least three months, and expected to continue full time for at least another three months. A centralized bill processing system provided the objective daily productivity data for each employee, including the number and types of bills processed, types of processing activities performed, and hours actually worked on the bill processing system.

For subjective measurements, participating employees were asked to provide daily responses to questions administered by telephone interactive voice response (IVR). Employees accessed the system by calling a toll-free number at the end of each workday and entered responses by pushing touch-tone buttons. The entire process took about five minutes. Self-reported productivity was measured each month by a seven-item questionnaire mailed to each participant.

We analyzed the daily objective measures of work productivity along with the employees’ self-reported daily responses and found a weak correlation between the two on average. In the monthly data, correlations between the self-reported measures of health effects on work and the objective productivity reports were low or nonexistent.

These pilot study results do not indicate that self-reporting is inaccurate. Rather, it appears that subjective and objective measures provide information about different aspects of work performance. Both types of measure may be necessary to fully capture the burden of illness and its treatment. Further studies are needed to explore the factors that determine subjective responses in order to better understand their relationship to objective performance measures and actual total impact on employers’ costs.

**Alternative View of Vocational Rehabilitation**

While the return of injured individuals to work is a primary goal of vocational rehabilitation programs, other factors – including a person’s job satisfaction and aspirations – are important measures of program effectiveness. Typically, these factors are overlooked, as with evaluations of vocational...
rehabilitation programs focusing only on employment status. This year we completed a study aimed at developing a broader measure for evaluating vocational rehabilitation programs. Our findings will help define a standard measure that will help industry, social services, insurance providers, and health services better assess the success of such programs.

Assisted by researchers at La Trobe University in Melbourne, Australia, we studied 170 people with spinal cord injuries. Researchers, experienced in vocational services, interviewed each participant individually, asking about their job status and their corresponding level of satisfaction. When applicable, we asked subjects what they would prefer to do, as well as what, if anything, they were doing to achieve their vocational goals.

Using this line of questioning, we found that at least 52 percent of study participants could benefit from some type of vocational assistance. Of the unemployed participants, 74 percent were unhappy with their job status, indicating a significant potential to improve outcomes in this area. Of the employed participants, 29 percent were not completely satisfied with their job situations, which suggests that ongoing retention services would potentially benefit this group.

Our findings indicated significant potential for using this broad-based interview approach as a guide and evaluation tool for measuring the effectiveness of vocational rehabilitation programs. This more comprehensive measure identifies individuals who could potentially benefit from vocational services and provides ways to determine an individual’s desired outcome. It also offers a way to collect baseline information about relevant behaviors that may help evaluate the effectiveness of vocational rehabilitation services.

**Return-to-Work Outcomes Among Older Workers**

With people living longer, healthier lives, and an increasing number remaining employed later in life, older workers are a growing segment of the workforce in the United States. The number of workers over age 55 workers is expected to increase by 10 to 15 percent over the next 10 years. To better understand the issues facing older workers, our researchers are conducting a prospective investigation of occupational injuries and illnesses among this group. Our goal is to identify effective interventions and return-to-work strategies to meet the unique needs of this worker population.

In collaboration with researchers from the University of Massachusetts, we collected survey responses from 2,000 injured workers in 2002. This brings us to a total of 3,000 injured workers surveyed, half between the ages of 20 and 55 and the other half over age 55. All were surveyed within six weeks of injury. Workers provided details on health, medical, demographic, economic, vocational, and social factors, as well as information on employer and medical responses to the injury.

Our continued data analysis revealed several unique issues in the older worker population. These include:

- a higher prevalence of second-career jobs with risks that are quite different from prior careers;
- slightly more chronic illnesses that may complicate recovery from a work-related injury; and
- retirement options that are not available to younger workers.

However, overall, older workers had higher job satisfaction, more stable employment, and reported a higher quality of medical care and more positive employer responses compared to younger workers. Follow-up data analysis is underway to determine how these differences relate to functional and return-to-work outcomes and those factors that are associated with optimal outcomes.

To better understand the issues facing older workers, we are conducting a prospective investigation of occupational injuries and illnesses among this group.
Erector Spinae Myoactivity and Low Back Pain

Low back pain continues to be the most prevalent and costly work-related musculoskeletal disorder facing the United States and other industrialized countries. Yet because of its many manifestations and causes, it remains one of the most difficult conditions to treat. Typically, physicians and other treatment providers rely on a patient’s subjective report of pain level and degree of functional impairment to determine an appropriate course of treatment.

As part of an effort to find new, less subjective sources of information, we began to investigate the relationship between electromyographic (EMG) activity of the lumbar musculature and changes in patient reports of low back pain symptoms over time. Ultimately, the findings from this study will indicate whether EMG measurements can be used to help direct a patient’s treatment program.

We recruited 32 low back pain patients to participate in the eight-week study. Nineteen individuals were also recruited as part of a no-pain control group. The low back pain group used a telephone reporting system to provide daily reports of low back pain symptoms using a zero to ten pain score scale. They also participated in up to eight clinic test sessions and completed functional assessments for each session.

Using a portable experimental station that includes a four-sensor surface EMG system and inclinometers, our researchers were able to track electrical activity of the lumbar muscles as well as trunk and pelvic position. Subjects were asked to perform a slow-paced trunk flexion and extension motion as if bending to touch their toes with the knees straight, in both a free-standing position and with the pelvis restrained. The movement was also performed in a sitting position. Researchers measured muscle activity during the eccentric (trunk flexion) phase and concentric (trunk extension) phase of the motion with EMG electrodes placed over the upper and lower lumbar region of the subject’s erector spinae.

A preliminary analysis of the raw data indicated that the amplitude ratios of the extension phase to the flexion phase at the lower lumbar (L5) region were markedly higher for the control group. The ratio was 105 percent greater in the free-standing condition, 71 percent greater in the restrained pelvis condition, and 84 percent greater in the seated condition. These findings suggest that, compared to the control group, the subjects with low back pain produce greater muscular activation during concentric contraction of the lower erector spinae than during the eccentric contraction.
Publications

Journal of Occupational Rehabilitation

A Social Psychology Approach to Measuring Vocational Rehabilitation Intervention Effectiveness

Disability and Rehabilitation

Improving the Physician Role in Evaluating Work Ability and Managing Disability: A Survey of Primary Care Practitioners

Journal of Occupational and Environmental Medicine

Impact of Case Manager Training on Worksite Accommodations in Workers Compensation Claimants With Upper Extremity Disorders
Causes and Predictors

It is estimated that more than one third of reported occupational injuries and illnesses result in days away from work. Through our studies into the causes and predictors of work-related disability, we seek to increase our understanding of factors that influence return-to-work outcomes. Our goal is to make recommendations that help improve medical and case management strategies, ultimately leading to fewer days away from work and safe and sustained employment following an injury.

Effects of Supervisor Training

We continued to investigate the effects of supervisor training on disability outcomes. In its third full year, this field-based investigation examines whether training supervisors to effectively respond to injured employees can reduce or even prevent disability. We study this question by implementing supervisor training workshops at various industrial sites, tracking changes in workers compensation claims before and after training, and administering surveys to supervisors and employees.

This year, we analyzed the workers compensation claims of an industrial food processing plant where we had administered supervisor training to selected departments. We found that in the seven months following training, the selected departments experienced a 47 percent reduction in claims and a 25 percent reduction in lost-time work claims as compared to the prior seven months. This improvement compared with a 27 percent reduction in claims and no reduction in lost-time work claims experienced by non-trained departments performing similar job tasks in the same time period.

In another part of the study, researchers analyzed and coded employee and supervisor interview data from four industries (retail clothing, food processing, nursing care, and synthetic fabrics manufacturing). We found a high level of agreement among supervisors and employees on the importance of such factors as accommodation, communication, responsiveness, empathy/support, validation, and follow-up. However, employees were more likely to stress the importance of communication, while supervisors were more likely to stress the importance of including employees in the decision-making process. We will use the informa-
tion from these interviews to further refine the supervisor training program and intervention assessment surveys for future industrial application.

**Back Pain Treatment in the Primary Care Setting**

As most cases of occupational low back pain are treated by a primary care physician (PCP), how these physicians manage patients has a significant effect on clinical and return-to-work outcomes. However, few investigations have evaluated the nature or extent of PCP involvement and influence on outcome in typical cases of occupational low back pain. In order to provide new information on these topics, we completed a study of occupational low back pain treatment by PCPs.

Our study looked at PCP involvement in the care of patients with work-related low back pain and explored the relationship between various aspects of care and medical costs, indemnity costs, and disability outcomes. We were particularly interested in determining whether treatment by a PCP (as opposed to treatment through another provider) decreases the length of a patient’s disability.

In collaboration with the General Medicine Division of Massachusetts General Hospital, we designed a study of patients with workers compensation back pain claims from four hospital-affiliated PCP practices. We extracted information on emergency room visits, radiographic studies, hospital admissions, and surgical procedures from medical records. Information on past back pain history and demographics was also collected. Data on the duration of work loss and claim costs, including medical, indemnity, and administration was extracted from insurers’ records.

Results indicated that PCP care was related to a greater total disability claim cost. However, when a PCP was involved in treatment, care often occurred relatively late in the course of persistent symptoms. Patients with a prior history of low back pain were more likely to see a PCP for a work-related back pain incident. But there was no relationship between number of prior PCP visits and the likelihood of visits to the PCP for an episode of work-related back pain. In fact, prior PCP visits for any reason were shown to lower the likelihood of seeing the PCP after an initial claim of occupational low back pain. Further studies are needed using a larger population to confirm these findings.

These preliminary results suggest that because visits to a PCP may occur relatively late in the course of treatment, the PCP does not often have a significant role in initial patient care. Thus, some PCP visits may actually be an early indicator for future risk of prolonged work absence from occupational low back pain.

**Treatments for Tetraplegic Spinal Cord Injuries**

We completed a study aimed at gaining a better understanding of types of treatments and total costs associated with work-related tetraplegic spinal cord injury (SCI). Initial findings suggested that patients with work-related tetraplegic SCI received similar treatments to those with non-work-related tetraplegic SCI in the first year post injury. However, in subsequent years, treatment of the two groups appeared to differ.

In collaboration with Boston Medical Center’s Department of Rehabilitation Medicine, we set out to describe the characteristics of those who experienced a work-related tetraplegic SCI and to describe the annual medical costs and types of treatments for the first five years post-injury. Cases were classified into three groups based on where along the spinal cord the injury occurred and the grade of injury according to the

*Through our studies into the causes and predictors of work-related disability, we seek to increase our understanding of factors that influence return-to-work outcomes.*
American Spinal Injury Association (ASIA). We also compared expenses and treatments among various motor levels of injury by classifying patients into three categories of severity. Treatment types included: initial hospitalization and acute rehabilitation during the first year post-injury, SCI-related subsequent hospitalization or rehabilitation, outpatient services, medications, medical supplies, durable medical equipment, personal care attendants, vocational rehabilitation, and ambulance/assisted transportation.

We identified 62 patients who met our selection criteria for the study. Represented industries included construction, transportation, retail, manufacturing, agriculture, utility, and service. Ninety-two percent of the patients identified were male. Falls and vehicular accidents accounted for the majority of injuries – 36 and 34 percent, respectively.

The extent and costs of first-year post-injury treatment for our workers compensation cases were similar to previously published estimates for non-work-related spinal cord injuries by severity group. However, subsequent year costs and overall amount of treatment were substantially higher for work-related tetraplegic SCI. Increased attendant care services accounted for a substantial portion of this disparity.

We are currently working to describe and compare the specific components of treatment associated with occupational tetraplegic SCI among the three motor level groups.

**Recurrences of Low Back Injuries**

We continued our study of occupational low back injury recurrence, with the goals of developing and testing new research and analytical methods related to recurrences and identifying factors that contribute to such recurrences. Ultimately, the information gained may help improve loss prevention interventions and promote safe, sustained return to work after an injury.

We identified approximately 2,100 cases of work-related low back injuries (defined as contusion, rupture, sprain, or strain) which occurred during a two-year period in a single jurisdiction – New Hampshire. We then classified the claims into three groups according to the type of recurrence:

- claim-based recurrence (at least one claim filed after initial claim),
- care-based recurrence (health care was utilized again), and
- disability-based recurrence (a second episode of work-related disability occurred).

Initial findings demonstrated that recurrence rates for medical care were highly sensitive to the length of the selected minimum between-episode gap (the time required between treatments to constitute a new episode). Recurrence rates based on disability gaps were less sensitive to variations in minimum between-episode gaps, once very short periods of disability (one to four days) were removed. We have also determined that the use of several definitions of recurrence prevents researchers from reaching a consensus on recurrence rates and identifying the factors relevant to a recurrence.

Initial findings from our study of occupational low back injuries indicated that reinjury rates were highly sensitive to the applied definitions of medical care or work disability recurrence.
Publications

**Spine**
Work-Related Outcomes in Occupational Low Back Pain

**Journal of Occupational Rehabilitation**
Occupational Upper Extremity Disorders: A Detailed Analysis of Work-Related Outcomes

**American Journal of Industrial Medicine**
Prognosis in Acute Occupational Low Back Pain: Methodologic and Practical Considerations
An important strategy in realizing the Research Institute's scientific potential is to form collaborative relationships with premiere research institutions around the world. To date, our partnerships include the Harvard School of Public Health; prominent universities in China, such as Tsinghua and Fudan; the University of Aberdeen in Scotland; the Finnish Institute of Occupational Safety and Health; and the British Health and Safety Laboratories.

The Research Institute also conducts various activities aimed at increasing awareness of occupational safety and health and enhancing worker safety. These endeavors include the Institute's Visiting Scholar Program as well as special awards to recognize excellence in safety and health research. Each of these extramural activities contributes to our expanding portfolio of global safety and health research and enhances our existing research programs.
China Research Partnerships

This year we expanded our collaborative efforts in China, a country faced with unique challenges of size, rapid industrialization, and social change. Our efforts support China’s commitment to improving workplace safety, and involve close collaboration with the State Administration of Work Safety Supervision (SAWS), which was established in 2001. This year, we worked closely with SAWS and leading Chinese universities to define a strategy for knowledge transfer, research collaborations, and shared intellectual capacity.

Tsinghua University

Among the 2002 highlights was the establishment of a new collaborative relationship with the premiere engineering university in China, Tsinghua University (Beijing). The Research Institute and Tsinghua formalized this partnership in October, when representatives from both organizations met in Beijing to sign the official agreement. Under this agreement, the Research Institute and Tsinghua will conduct joint research to help reduce the occupational injury burden in China. As with our other partners in China, we will share joint research findings worldwide through peer-reviewed publication.

China International Forum on Work Safety

In a first-time event, Liberty Mutual co-sponsored the China International Forum on Work Safety with SAWS and the International Labor Organization (ILO). The theme of the two-day forum, which was held in Beijing in October, was “Work Safety and Occupational Health in the 21st Century.”

Keynote speakers included Shan Chunchang, deputy administrator of SAWS, who spoke about China’s safe work conditions, improvements, and countermeasures; and Liberty Mutual Vice President and Research Institute Director, Tom Leamon, Ph.D., who delivered an address on controlling the cost of unsafe workplaces. Other speakers included David Lauriski, United States Assistant Secretary of Labor for Mine Safety and Health, who spoke on mining safety supervision in the United States; and Dr. Jukka Takala, ILO representative, who presented on safe work for the world and related challenges.

There were several sessions covering topics on workplace safety in Chinese industry, global occupational health and safety research and practices, and challenges associated with accident insurance. Nearly 40 specialists and experts from dif-
Different countries also presented research papers at the forum, covering topics such as safety laws and regulations, occupational safety management systems, occupational hazards, and safe work education.

Held in conjunction with the China International Forum on Work Safety, the Fourth Annual Liberty Mutual Safe Work Forum focused on traffic safety issues. More than 60 participants attended the event, including health and safety experts, government officials, and representatives from international enterprises. Attendees participated in roundtable discussions on the contribution of research to traffic safety and the role of organization and regulation on highway traffic safety. In addition, participants looked at various case studies and exchanged views on the implications for China.

Liberty Mutual-Harvard Program in Occupational Safety and Health

Our efforts to establish a doctoral program in Occupational Injury Epidemiology and Safety Science with the Harvard School of Public Health marked a major milestone this year. A year-long faculty search reached a conclusion with the hiring of injury epidemiologist Melissa Perry, Ph.D., to spearhead the occupational injury program in the Department of Environmental Health. Dr. Perry served as an Instructor in Occupational Health for the Department of Environmental Health since joining the faculty at Harvard in 1999. Prior to that, she held academic appointments at the Medical College of Wisconsin and the University of Vermont. In addition to the new faculty appointment, the program produced the first Harvard School of Public Health doctoral graduate with a concentration in ergonomics.

The Liberty-Mutual Harvard Program maintained steady progress on several research projects including a study of sharps-related injuries among hospital workers (see p. 7), an investigation of the impact of physician practice patterns on length of disability (see p. 33), and a study of the relationship between chiropractic care and return to work (p. 27). Program researchers also completed work on a study of risk factors for acute traumatic hand injuries (see p. 9).

Scientific Visitors Advisory Board

The heads of five premiere international research organizations convened at the Research Institute in October for the second annual meeting of the Scientific Visitors Advisory Board (SVAB). In addition to learning about research developments through staff presentations and laboratory tours, SVAB members exchanged valuable insights on the expanding scope of the Institute and the development of the new facilities.
Honors Received

**Alice Hamilton Award**

The American Industrial Hygiene Association (AIHA) presented Institute Researcher, Barbara S. Webster, RPT, PA-C, with the 2002 Alice Hamilton Award. One of AIHA’s highest honors, the award is presented annually to an outstanding woman who has made a definitive, lasting achievement in the field of occupational and environmental hygiene. This accomplishment may involve public and community service, social reform, innovations or advancements in the scientific approach to the recognition, evaluation, and control of workplace hazards.

Nominated for her work in the areas of cost and disability burdens of musculoskeletal disorders and the diagnosis and treatment of work-related low back pain, Ms. Webster holds a long tradition of professional and community service in the health care profession. She received the award at the opening general session of the AIHA annual conference on June 3 in San Diego, California.

**Otto Edholm Award**

The Ergonomics Society named Research Institute Director, Tom B. Leamon, Ph.D., the 2002 winner of the Otto Edholm Award. The award recognizes significant contributions to basic or applied research in ergonomics. Dr. Leamon was selected for his work in developing and leading the Research Institute and for his earlier contributions in industry and academia. Ergonomics Society President, Magdalen Galley presented the medal at the Annual Ergonomics Society Conference held in April in Cambridge, England.
Awards Presented

Liberty Mutual Prize

Hongwei Hsiao, Ph.D., of the National Institute for Occupational Safety and Health, Bruce Bradtmiller, Ph.D., of Anthrotech, Inc., and Jennifer J. Whitestone, of Total Contact, Inc., won the 2002 Liberty Mutual Prize. Jointly sponsored with IEA, the award recognizes outstanding, original research in the field of occupational safety and health.

The winners received this recognition for their research, published in the paper, “Sizing and Fit of Fall-Protection Harnesses.” Their investigation into a full-body, fall-protection harness system provided the first detailed, three-dimensional anthropometry of construction workers and identified 15 representative body models for standard-size harness design. The study also revealed deviations between traditional measurements and the three-dimensional scans.

Best Paper Award

Faculty of Engineering Professors, Mitsunori Kubo, Dr. Eng., Fumio Terauchi, Ph.D., and Hiroyuki Aoki, Dr. Eng., of the Department of Design and Architecture at Chiba University (Chiba, Japan), and Faculty of Science and Technology Professor, Yoshiyuki Matsuoka, Ph.D., of Keio University (Kanagawa, Japan) won the 2002 Liberty Mutual Best Paper Award. The annual award recognizes the best paper published in the International Journal of Industrial Ergonomics during the prior year and reflects our commitment to quality research into the reduction of workplace pain and suffering.

The award recipients authored “An Investigation into a Mechanical Vibration Human Model Constructed According to the Relations Between the Physical, Psychological, and Physiological Reactions of Humans Exposed to Vibration.” The winning paper describes a study in which researchers developed a mechanical vibration model to simulate the physical reactions of the human body when exposed to external vibrations.

The investigation revealed resonance points from head, chest, and abdominal shaking in the frequency range 2–11 hertz. The study also revealed a relationship between the physical reactions and the resulting psychological and physiological reactions. The synthetic vibration model has significant implications in the field of industrial design, particularly in the automotive industry.
The Visiting Scholar Program entered into its eighth year of offering unique collaborative experiences for senior researchers from around the world. Kai Way Li, Ph.D., of Chung-Hua University in Taiwan, was this year’s Visiting Scholar. An associate professor with the Department of Industrial Management, he has research interests in occupational injury prevention, including slips and falls and hand tool design. In the area of slips and falls, he specializes in gait analysis, friction measurement, and perception.

During his three-month stay at the Institute, Dr. Li collaborated with our researchers to design a field investigation of work-related slips and falls in restaurants. The study explores the relationship between actual floor friction measurements and worker perceptions of floor slipperiness. Dr. Li and Institute researchers surveyed restaurant workers from various sites of a single restaurant chain. Participants were asked to rate the slipperiness of selected areas of the kitchen. They were also asked about their job experience, work duties, foot-wear, and other factors that might affect their perception of floor slipperiness. The information provided by workers will be compared to actual floor friction measurements taken by researchers in the kitchens of participating restaurants.

Dr. Li continues to collaborate with the Institute on the restaurant study. Using similar protocols, he implemented a parallel study in Taiwan. Dr. Li and Institute researchers will compare the results of both studies and will work together towards publication of their joint research findings. Plans are also underway for future collaboration on another slips and falls experiment in Taiwan.

At Chung-Hua University, Dr. Li has served as special assistant to the president, chairman of the Department of Transportation Management, and the executive director of the Extension Education Center. In 1991, Dr. Li received his Ph.D. in industrial engineering from Texas Tech University, Lubbock. He earned his M.S. in Industrial Engineering from the University of Texas at Arlington, and his B.S. in Civil Engineering from the National Chiao Tung University.
Publications


Buchholz, B.,44, Paquet, V.35, Wellman, H., and Forde, M.27, “Quantification of Ergonomic Hazards for Iron Workers Performing Concrete Reinforcement Tasks During Heavy Highway Construction,” accepted for publication in American Industrial Hygiene Association Journal


Chen, C.L.21, Kaber, D.B.22, and Dempsey, P.G., “Using Feedforward Neural Networks and Forward Selection of Input Variables for an Ergonomics Data Classification Problem,” accepted for publication in Human Factors and Ergonomics in Manufacturing


Dempsey, P.G., McGorry, R.W., and Holihan, R., “Novel Solutions for a Difficult Materials Handling Problem,” accepted for publication in *Ergonomics in Design*


Feuerstein, M., Shaw, W.S., Lincoln, A.E., Miller, V.I., and Wood, P.M., “Clinical and Workplace Factors Associated with a Return to Modified Duty in Work-Related Upper Extremity Disorders,” accepted for publication in *Pain*

Filiaggi, A.J. and Courtney, T.K., “Responding to Disabling Occupational Injuries in Restaurants: Practice-Based Approaches,” accepted for publication in *Professional Safety*

Fisman, D.N., Harris, A.D., Sorock, G.S., and Mittleman, M.A., “Sharps-Related Injuries in Health Care Workers: A Pilot Case-Cross-over Study,” accepted for publication in *The American Journal of Medicine*


Gielo-Perczak, K. and Karwowski, W., “Ecological Models of Human Performance Based on Affordation, Emotion and Intuition,” accepted for publication in *Ergonomics*


Karwowski, W., Siemionow, W., and Gielo-Perczak, K., “Physical Neuroergonomics: The Human Brain in Control of Physical Work Activities,” accepted for publication in *Theoretical Issues in Ergonomics Science*


Lincoln, A.E., Smith, G.S., Amoroso, P.J., and Bell, N.S., "The Effect of Cigarette Smoking on Musculoskeletal-Related Disability," accepted for publication in American Journal of Industrial Medicine


Pransky, G., Shaw, W.S., and McLellan, R., "Employer Attitudes, Training, and Return-to-Work Outcomes: Addressing Barriers to Ergonomic Intervention and Rehabilitation," accepted for publication in Assistive Technology


Robertson, M.M., Maynard, W.S., and McDevitt, J.R., "Telecommuting: How Do We Manage Health and Safety of Alternative-Site Workers?," accepted for publication in Professional Safety


Roetting, M., “Little Dictionary of Eye Movement Parameters German-English and English-German,” accepted for publication in MMI Interaktiv

Shaw, W.S., Feuerstein, M., Miller, V.I., Lincoln, A.E., Berger, R., and Wood, P.M., “Clinical Tools to Facilitate Workplace Accommodation After Treatment for an Upper-Extremity Disorder,” accepted for publication in Assistive Technology


Smith, G.S., Howland, J., Hadley, J., Keyl, P., and Foss, R., “Risk of Disease Associated with Low BACs: Lessons Outside the Highway,” accepted for publication in Transportation Research Board Circular


Wellman, H., Lehto, M., Sorock, G.S., and Smith, G.S., “Computerized Coding of Injury Narrative Data from the National Health Interview Survey,” accepted for publication in Accident Analysis and Prevention

Young, A.E. and Murphy, G.C., “Vocationally-Oriented Rehabilitation Service Requests: The Case of Employed Persons Experiencing a Spinal Cord Injury,” accepted for publication in Australian Journal of Career Development


1Aachen University of Technology 2AgResearch, Ltd. 3Army Research Institute of Environmental Medicine 4Atlantic Charter Insurance Company 5Beth Israel Deaconess Medical Center 6Boston University 7Brigham and Women’s Hospital 8Center for Occupational Rehabilitation 9Columbia University 10Duke University 11Exeter Hospital 12Finnish Institute of Occupational Health 13Georgetown University 14George Washington University 15Harvard University 16Health and Work Outcomes 17Indiana University 18Johns Hopkins University 19Keimyung University 20LaTrobe University 21National Chengchi University 22North Carolina State University 23Ohio State University 24Oregon Health and Science University 25Portland State University 26Purdue University 27St. George’s University 28Social Sectors Development Strategies 29Stanford University 30State University of New York at Buffalo 31Steelcase Corporation 32Texas Tech University 33The Cleveland Clinic Foundation 34The Tenants’ and Workers’ Support Committee 35U.S. Department of Labor, Office of Workers Compensation Programs 36U.S. Department of Veterans’ Affairs 37United Services of the Health Sciences 38Union Memorial Hospital 39University of Alberta 40University of California at Davis 41University of California at San Diego 42University of Louisville 43University of Maryland 44University of Massachusetts 45University of North Carolina 46University of Texas 47University of Washington 48University of Wisconsin 49W.E. Upjohn Institute 50Weill Medical College of Cornell
Chien-Chi Chang, Ph.D.

Theodore K. Courtney, M.S., C.S.P.
China International Forum on Work Safety, “Frequent, Costly, and Disabling Injuries in the Construction Industry,” Beijing, People’s Republic of China, October 10-11

Krystyna Gielo-Perczak, Ph.D.
Biomechanics in the Decade of Bone and Joint, “Musculoskeletal Modeling in Biomedical Education,” Brussels, Belgium, April 27-29

Yueng-Hsiang Huang, Ph.D.
17th Annual Conference of the Society for Industrial and Organizational Psychology, “Environmental Control and Workplace Design on Performance, Effectiveness, and Collaboration” Toronto, Canada, April 12-14
European Academy of Occupational Health Psychology, “Attitude Towards the Application of Augmented Feedback in the Trucking Industry” and “Effects of Office Ergonomics Training on Environmental Control, Environmental Satisfaction, Communication, and Psychological Stress,” Vienna, Austria, December 4-6

Tom B. Leamon, Ph.D.
The Hong Kong Polytechnic University Department of Rehabilitation Sciences Ergonomics and Human Performance Seminar, “The Liberty Model in Occupational Safety and Health - Disability Assessment and Management of Work Injuries,” Hong Kong, People’s Republic of China, March 12
Association of Workers Compensation Boards of Canada Knowledge Transfer Conference, “Effective Knowledge Transfer: Getting the Ideas and Information to Those Who Need It,” Toronto, Canada, November 18-20

Jia-Hua Lin, Ph.D.
National Tsinghua University, “A Dynamic Biomechanical Model of the Human Operator Response to Impulsive Reaction Forces,” Taiwan, People’s Republic of China, May 15

David A. Lombardi, Ph.D.

Rammohan V. Maikala, Ph.D.
Aerospace Medical Association 73rd Annual Scientific Meeting, “Cerebral Hemodynamic Responses in Healthy Men and Women,” Montreal, Canada, May 4-7
American College of Sports Medicine 49th Annual Meeting, “Cardiorespiratory and Muscle Oxygenation Comparisons During Arm Cranking and Task Specific Pushing-Pulling in Healthy Women,” St. Louis, MO, May 29-June 1
United States Army Labs Invited Presentation, “Cerebral and Muscle Hemodynamics During Whole-Body Vibration,” Natick, MA, June 11

Glenn S. Pransky, M.D., M.Occ.H.
Presentations

10th International Congress on Occupational Health Services, “The Effectiveness of Occupational Health and Safety: What Measures Can We Trust?,” Amsterdam, The Netherlands, November 13-16

Michelle M. Robertson, Ph.D., C.P.E.


Matthias Roetting, Ph.D. and Yueng-Hsiang Huang, Ph.D.

William S. Shaw, Ph.D., P.E.


The Seventh Annual Meeting of the Disability Management Employers Coalition, “IDM Breakthrough: The Power of Enlightened Supervision,” San Antonio, TX, August 7


Gary S. Sorock, Ph.D.
Measuring the Burden of Injury, “Computerized Coding of Injury Narrative Data from the NHIS,” Montreal, Canada, May 16-17


Barbara S. Webster, R.P.T., P.A.-C.


Amanda E. Young, Ph.D.
Research Institute personnel participate in a variety of professional organizations, societies, and activities related to their respective areas of expertise. These opportunities allow researchers to interact with their peers, gain valuable scientific input, and recommend change in the standards and practices applicable to their fields. In addition, many of our researchers serve on review committees and editorial boards for leading health and safety scientific journals. Listed here are the organizations to which our researchers belonged, the activities in which they participated, and the journals for which they served as reviewers in 2002.

Organizations and Societies

American Academy of Physician Assistants
American College of Epidemiology
American College of Occupational and Environmental Medicine
American College of Sports Medicine
American Economic Association
Association for Computing Machinery
American Industrial Hygiene Association
American Pain Society
American Physical Therapy Association
American Psychological Association
American Public Health Association
American Society of Biomechanics
American Society of Mechanical Engineers
American Society of Safety Engineers
American Society of Safety Engineers Foundation
American Society for Testing and Materials
American Statistical Association
Association for the Advancement of Automotive Medicine
Association for Comparative Economic Studies
Australasian Epidemiological Association
Board of Certified Safety Professionals
Ergonomics Society
German Association of Biomedical Engineering
German Association for Electrical Engineering, Electronics and Information Technologies
German Ergonomics Society
German Informatics Society
Human Factors and Ergonomics Society
Institute of Electrical Engineers
Institute of Industrial Engineers
International Association for Rehabilitation Research
International Council on Alcohol, Drugs, and Traffic Safety
International Epidemiological Association
International Society of Biomechanics
Massachusetts Association of Physician Assistants
National Academy for Social Insurance
New England Society of Applied Psychology
Psychophysiology in Ergonomics
Public Health Association of New Zealand
Society for Epidemiologic Research
Society of Industrial and Organizational Psychology
System Safety Society

Activities

Academy for Health Services Research and Health Policy
American Society of Safety Engineers Foundation
- Research Committee Member
BIOMCH-L
- Co-moderator Electronic Discussion Forum
Commonwealth of Massachusetts Board of Registration of Physicians Assistants
- Chair
Harvard Occupational Injury Prevention Program
- Advisory Committee
Human Factors and Ergonomics Society
- Executive Council Member, Secretary, Treasurer
International Collaborative Effort on Injury Statistics
- Coordinator, Sentinel Injury Evaluation Project
International Human Computer Interaction Symposium
- Scientific Advisory Board
International Commission on Occupational Health
Mass Medical Society
Physician Health Program
and Advisory Committee
- Board of Directors
National Center for Health Statistics
- Consultant
National Safety Council
- International Conference on
  Injury Committee
National Study Center for Trauma
  and EMS, University of Maryland
  - Consultant
New England College of Occupation-
  al and Environmental Medicine
  - Board of Directors
National Institute for Occupational
  Safety and Health
  - National Occupational
    Research Agenda Liaison
  - Traumatic Injury Study Team
  - Musculoskeletal Injury
    Study Team
Organizational and Design
International Symposium
- Scientific Advisory Board
Transportation Research Board
- Committee on Simulation and
  Measurement of Vehicle and
  Operator Performance
- Committee on Vehicle
  User Characteristics
Workers Compensation
Research Group
- Steering Committee

**Journal Reviews**

*Accident Analysis and Prevention*

*American Industrial Hygiene
Association Journal* *

*American Journal of Epidemiology*

*American Journal of Industrial Medicine*

*American Journal of Public Health*

*Annals of Epidemiology*

*Applied Ergonomics*

*Assistive Technology*

*Behaviour and Information
Technology*

*Disability and Rehabilitation*

*Ergonomics*

*Environemental Health* *

*Human Factors*

*Injury Prevention* *

*International Journal of
Industrial Engineering*

*International Journal of
Industrial Ergonomics*

*International Journal of
Occupational Safety and Ergonomics*

*Journal of the American
Medical Association*

*Journal of Family and
Economic Issues*

*Journal of Occupational and
Environmental Medicine*

*Journal of Occupational
Rehabilitation*

*Journal of Safety Research*

*Journal of Tribology*

*MMI-Interaktiv*

*New England Journal of Medicine*

*Occupational and
Environmental Medicine*

*Occupational Ergonomics* *

*Safety Science*

*Social Science and Medicine*

*Theoretical Issues in Ergonomics Science* *

*Editorial Board*
Each year, the Research Institute welcomes visitors from industry, academia, and government to tour the facilities and learn about our research programs. In 2002, we hosted the following visitors from around the world:

- **AAPA-Occupational Medicine**  
  - Alexandria, VA
- **AMT**  
  - McLean, VA
- **Advanced Common Sense**  
  - Chestnut Hill, MA
- **Applied Sciences Laboratory**  
  - Bedford, MA
- **Association for Manufacturing Technology**  
  - McLean, VA
- **Boston College**  
  - Chestnut Hill, MA
- **Boston Globe**  
  - Boston, MA
- **Cancer Care Ontario**  
  - Toronto, Canada
- **Cloutier Consulting Services**  
  - Cincinnati, OH
- **Columbia University**  
  - New York, NY
- **Cook County Hospital**  
  - Chicago, IL
- **Coomeva International**  
  - Colombia, South America
- **Deere and Company**  
  - Moline, IL
- **Design Safety Engineering**  
  - Ann Arbor, MI
- **Exelon Corporation**  
  - Chicago, IL
- **Finnish Institute of Occupational Health**  
  - Helsinki, Finland
- **FirePsych, Inc.**  
  - Norwood, MA
- **General Motors**  
  - Troy, MI
- **Health and Safety Laboratory**  
  - Sheffield, England
- **Heilind Electronics**  
  - Wilmington, MA
- **IBM**  
  - Waltham, MA
- **IBM Watson Research Center**  
  - Yorktown Heights, NY
- **Institut National de Recherche et de Sécurité**  
  - Paris, France
- **Institute of Occupational Medicine and Industrial Hygiene**  
  - Taipei, Taiwan
- **Insurance Information Institute**  
  - New York, NY
- **Iron Mountain, Inc.**  
  - Boston, MA
- **Johnson Wax**  
  - Sturtevant, WI
- **Key Energy Services, Inc.**  
  - Midland, TX
- **Kimball International**  
  - Jasper, IN
- **King Kullen Grocery Co., Inc.**  
  - Bethpage, NY
- **Marsh USA, Inc.**  
  - Louisville, KY
- **Matworks**  
  - Beltsville, MD
  - Glenwood, MD
- **Mount Holyoke College**  
  - South Hadley, MA
- **NIOSH**  
  - Morgantown, WV
- **Northeastern University**  
  - Boston, MA
- **Rensselaer Polytechnic Institute**  
  - Troy, NY
- **SensoMotoric Instruments, USA, Inc.**  
  - Needham, MA
- **Straub Clinic**  
  - Honolulu, HI
- **Technical University of Berlin**  
  - Berlin, Germany
- **Terra Lycos**  
  - Waltham, MA
- **Tufts University**  
  - Medford, MA
- **Travelers Insurance Co.**  
  - Hartford, CT
- **University of Connecticut**  
  - Hartford, CT
- **University of Massachusetts**  
  - Amherst, MA
- **University of New Hampshire**  
  - Durham, NH
- **US Bureau of Labor Statistics**  
  - Boston, MA
  - Washington, DC
- **Victorian WorkCover Authority**  
  - Melbourne, Australia
- **Wal-Mart Stores, Inc.**  
  - Bentonville, AR
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Take 90 west to Exit 11A (495 South). Take 495 south to Exit 21A (W. Main St. Hopkinton). Go east on W. Main St., which becomes Rte. 135. Proceed on 135 through the lights at Hopkinton Center (Colella’s grocery store). About a mile and a half past Hopkinton Center, bear left past Hopkinton Center (the turn is at the crest of a small hill; a small sign indicates where you enter for Frankland Road). On Frankland Road, follow the signs to the Research Institute. The entrance will be on your left after a long, stone fence.

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The Liberty Mutual Research Institute for Safety in Hopkinton, Massachusetts, is a company-owned and operated occupational health and safety research facility. The Research Institute is recognized throughout the world for its continuing contributions to the prevention of workplace injuries and to the control of work-related disability.

The Institute houses two entities, the Center for Safety Research (CSR) and the Center for Disability Research (CDR). The CSR investigates the causes of accidents and injuries, human capacities for various job tasks, and ways to enhance on-the-job safety. The CDR studies the causes, consequences, and prevention of disability in workers, and aims to achieve safe and sustained return to work for injured workers.

Through broad-based research programs and in close collaboration with researchers and practitioners around the world, the Research Institute is dedicated to a common purpose, embodied in the Liberty Mutual Creed, **to help people live safer, more secure lives.**