Manual materials handling (MMH) refers to tasks that involve the movement or manipulation of objects using human effort. Although modern advances in automation, such as power lifts, power tuggers, carts, and other mechanical handling equipment, have reduced the need for human exertion in some jobs, manual materials handling tasks will continue to be an integral part of the workplace for the foreseeable future. Millions of workers from restaurants, warehouses, construction sites, and other industries perform, and will continue to perform, these tasks every day.

Why should businesses be concerned about manual materials handling? According to a 1999 Liberty Mutual Research Institute study, five basic manual materials handling tasks—lifting, lowering, pushing, pulling, and carrying—account for more than a quarter of all compensable work injuries. The majority of these injuries are musculoskeletal disorders, such as strains, sprains, and back pain. Whether sudden or gradual, musculoskeletal disorders typically occur when the job requirements exceed a worker’s physical capabilities. Overexertion, a consequence of workers exceeding their physical capabilities, is the longstanding number one cause of disabling work-related injuries in the United States (2006 Liberty Mutual Workplace Safety Index). The majority of overexertion injuries are related to manual materials handling.

“A waiting carries an overloaded tray and strains his back.

“A warehouse worker lifting a heavy box twists into an awkward position and injures her back.

“A construction worker lifts a large stack of two by fours and sprains his shoulder.

What do all of these unfortunate situations have in common? In each scenario, the worker was involved in a manual materials handling activity at the time of injury.

“Understanding the underlying risk factors that can lead to overexertion is the first step in reducing manual materials handling injuries,” states Y. Ian Noy, Ph.D., director of the Liberty Mutual Research Institute. “Weight is not the only factor that determines if a job can be performed safely. There are so many other elements, such as handling frequency, task duration, individual worker differences, and postures, which can increase the risk of overexertion. It is important to look at all of these factors when assessing a task and to evaluate their total impact on job task safety.”

For more than 50 years, the Liberty Mutual Research Institute for Safety has conducted laboratory and field studies to investigate various factors associated with manual materials handling tasks. Findings have been used to develop guidelines, products, and ergonomic recommendations to help protect workers from injury.

Today, Institute research scientists continue to conduct cutting-edge research with the aim of reining existing standards and advancing knowledge on the causes and prevention of manual materials handling injuries. “The more we can understand about the factors that contribute to manual materials handling injuries, particularly the underlying biomechanical, physiological, and environmental mechanisms, the better we can help businesses protect their workers,” concludes Noy.
Handling

From Modest Beginnings to State of the Art

R-r-r-ing... A man dressed in scrubs lifts a bin weighted with steel shot from the floor while a researcher takes some observational notes. The man reaches up and places the bin on a shelf. Sh-sh-oop... The shelf automatically lowers back to floor height. The man patiently waits. R-r-r-ing ... the man again lifts the bin, reaches up, and places it on the shelf. Sh-sh-oop... the shelf returns. Feeling a bit fatigued, he removes some of the steel shot. R-r-r-ing... and the process continues – all in a day of simulated work in the manual materials handling laboratory at the Liberty Mutual Research Institute for Safety.

(Continued next page)

Factors Impacting MMH

Fatigue
Discomfort
Injury
Quality
Performance

Task Demands

Material
- Dimensions
- Coupling
- Symmetry

Environment
- Heat • Cold
- Vibration

Task/Workplace
- Frequency
- Distance moved
- Work height
- Obstructions

Task Demands

Task/Workplace

Environment

Worker Capacity

Personal
- Height • Weight
- Age • Smoking
- Injury history

Biomechanical
- Spinal strength
- Joint strength

Psychological
- Coordination
- Psychosocial perceptions

Physiological
- Physical work capacity
- Conditioning

The ratio of task demands to worker capacity during manual materials handling influences the occurrence of potential undesirable effects, such as fatigue, discomfort, and injury, as well as productivity and quality.


Vol. 10, No. 2 2
Since its beginnings, the Research Institute has simulated jobs that involve manual materials handling—lifting, lowering, pushing, pulling, and carrying—to study the dynamics of these tasks with the goal of improving worker safety. For industry, manual materials handling is the most frequent and costly category of loss, comprising more than one fourth of all compensable work injuries. The majority of these injuries involve low back pain. Further, the annual Liberty Mutual Workplace Safety Index reports that overexertion—joints most often caused by manual materials handling—is the leading cause of disabling workplace injury. In 2006, the Index estimated $13.6 billion in direct U.S. workers compensation costs due to disabling overexertion injuries.

A Look Back in Time

The Research Institute has played an integral role in the development of industry guidelines and assessment tools used by ergonomists to reduce manual materials handling risks. As far back as the 1950s, under the direction of Willem S. Frederik, M.D., Ph.D., Liberty Mutual researchers studied some of the physiological aspects of manual materials handling tasks. These inaugural investigations examined how various task factors, such as pushing forces and repetitions, impacted human fatigue. During simulated industrial work tasks, researchers measured oxygen consumption using custom-designed equipment, including the Differential Flameoxymeter. This device, developed by Frederik, enabled researchers to measure continuous oxygen consumption. It was a hallmark of the time.

The Psychophysical Approach Emerges

In 1962, Stover H. Snook, Ph.D., joined the Institute staff as a project director and continued Frederik’s work. In his first study, Snook investigated a common industrial lifting task to determine the maximum number of lifts per minute that workers could perform without excessive fatigue. The study produced the concept of “group work capacity” — the percentage of workers that can perform a task without showing physiological signs of fatigue. In the lab, Snook and colleagues measured oxygen consumption and heart rates from a sample of industrial workers to estimate the group work capacity for different lifting frequencies, heights, and weights. This novel, ergonomic-centered approach focused on designing the task to fit the worker, versus prior methods of selecting the worker to fit the job. With this methodology, the goal was to design tasks that could accommodate up to 90 percent of all workers.

“After completing the first experiment, I became concerned that we were only looking at part of the problem,” recalls Snook, who is now retired. “Certainly, I recognized task frequency as an important component, especially for repetitive lifting tasks. But, I also knew that weight was at least as, if not more important, for the intermittent lifting tasks common in industry.” Consequently, Snook began to explore the use of psychophysics—an established method used in experimental psychology—to investigate industrial manual materials handling tasks. Psychophysics examines the relationships between physical stimuli and sensory perception. Scientists had successfully used this method to develop the decibel scale and the effective temperature scale. Snook was convinced that he could use this same approach to develop a scale of maximum acceptable weights and forces for manual materials handling tasks. “Psychophysics allowed us to evaluate manual handling tasks more thorough and better assess injury risk, whereas other approaches had limitations,” notes Snook.

Using psychophysics, Snook and his colleagues refined their earlier experiments by allowing study participants to control the weight of the handled objects. The researchers instructed subjects to lift as much as possible without straining themselves or becoming un-
usually tired, weakened, overheated, or out of breath. As study participants varied the weights of the objects to acceptable levels, researchers recorded physiological and performance data. From these investigations, Snook published seminal papers that reported the effects of age and physique on continuous work capacity and defined maximum weights and workloads that were acceptable to industrial populations.

With the continued prevalence of manual materials handling injuries, the Research Institute expanded its psychophysical research throughout the 1960s and 1970s to include studies of pushing, pulling, and carrying tasks. Special instrumentation and software programs were developed for data analysis. And, unlike other research programs, which often used young, healthy college students as study participants, the Research Institute only recruited experienced industrial workers to reflect the real worker population.

**A New Metric: The Manual Materials Handling Tables**

In 1969, Vincent M. Ciriello, Sc.D., joined the staff. Together, Ciriello and Snook broadened the manual materials handling research to include females and to incorporate increased lift distances and frequencies. In 1978, Snook and Ciriello combined the results of seven key studies into a series of tables. That same year, Snook was invited to present this work at the Ergonomics Society’s annual keynote lecture in Cranfield, England. The resulting paper, “The Design of Manual Handling Tasks,” revolutionized the occupational safety and health community. “The paper was significant because it provided a metric for assessing manual materials handling risk,” says Ciriello, who continues his work as a Research Institute scientist to the present day. According to Ciriello, manual materials handling guidelines were somewhat arbitrary prior to the tables. “Most guidelines simply recommended a single maximum weight. The tables, which incorporated individual differences and various task parameters, allowed safety professionals to determine the maximum acceptable weights for different percentages of the population. This information gave practitioners a firm basis for identifying and recommending ergonomic solutions.”

**Reframing Research**

Throughout the late 1970s and into the 1980s, Ciriello and Snook expanded their psychophysical investigations of manual materials handling tasks. They conducted four key studies to examine various object sizes and handle types, additional frequencies, extended reaches, and task combinations. The studies incorporated larger subject samples and more females. The results, presented in the 1991 *Ergonomics* paper, “The Design of Manual Handling Tasks: Revised Tables of Maximum Acceptable Weights and Forces,” provided industry with an improved manual handling task evaluation tool. In addition, the National Institute for Occupational Safety and Health (NIOSH) incorporated some of the study results into the 1993 Revised NIOSH Equation for the Design and Evaluation of Manual Lifting Tasks, a tool that is widely used by U.S. industry.

**Biomechanics: New Investigative Technologies**

In the early 1990s, the Research Institute began applying biomechanical methodologies to manual materials handling investigations. The availability of sophisticated motion analysis equipment and biomechanical modeling methods enabled researchers to observe, quantify, and analyze the underlying biomechanical mechanisms involved in these tasks. Research Institute scientists continue to use these technologies to observe workers in the laboratory as they perform simulated tasks using various workstation setups and work conditions. Over the years, they have collected extensive data on postures and the associated joint stresses imposed on the worker during the simulated tasks.

Using data collected in early biomechanical experiments, Liberty Mutual researchers set out to advance eld-based data collection capabilities. In the mid-1990s, they identified several key postures that, when applied to existing biomechanical simulation models, could successfully approximate the forces and stresses on the body throughout an entire lift cycle. With this information, they developed a computerized video posture coding method to identify key lifting postures and joint angles. This method formed the basis of VidLiTeC™, short for Video-Based Lifting Technique Coding System. “VidLiTeC made it possible to evaluate manual materials handling tasks in actual industrial settings,” says Research Scientist Chien-Chi Chang, Ph.D.
This on-site data collection capability gave researchers and ergonomists the ability to estimate, with reasonable accuracy, low back compression forces (at the L5/S1 joint) in addition to the stresses involved at other major joints during industrial lifting and lowering tasks. "In the past, this type of data could only be acquired using complex motion analysis equipment, which was extremely difficult to apply in industrial settings," explains Chang. "VidLiTeC enabled ergonomists and researchers to acquire this information easily and effectively at the work site with only minimal disruption to workers and work processes."

**Into the New Millennium**

Today, Institute researchers continue to investigate manual materials handling tasks, while seeking to develop new models to better correlate with today's changing workplace. Jobs involving these tasks have become more complex and often include a variety of combined tasks. In addition, the population itself has changed, as illustrated by findings from a Research Institute experiment conducted during the late 1990s. The experiment, which focused on refining the data on lowering tasks with respect to distances, different size boxes, and frequencies, also revealed an interesting secular trend. Despite the same psychophysical instructions and experimental set up as used in prior studies, the more recent study indicated that modern-day workers were selecting dramatically lower weights than their predecessors. To test the trend, Institute researchers collected extensive task data from 52 industrial workers between the years 2002 and 2006. An analysis of the data verified that current study populations selected weights up to 41 percent lower than previous study populations, depending on the task. "This finding has significant implications for field evaluations of manual materials handling tasks," says Ciriello, noting that further research is needed to better understand the reasons behind this unexpected result.

As part of this same study, researchers took a more comprehensive look at some of the physiological costs imposed on workers. Using the latest technologies, researchers observed and measured subjects' heart rates, oxygen uptake, and muscle oxygenation during simulated work tasks. Today, researchers are using these data to develop improved models for estimating the physiological costs associated with manual materials handling tasks in the workplace.

"For more than half a century, the Institute's scientific innovation and excellence in manual materials handling research has defined new, robust approaches to controlling risks," states Y. Ian Noy, Ph.D., director of the Research Institute. "Our research continues to impact today's workplaces. As we break new ground in biomechanical and physiological research, we continue to update and refine our manual materials handling studies to reflect the realities of the 21st Century global work environment. I am confident that we will build upon and add to our rich legacy."
Reduce accidents, lost-time, absenteeism, turnover, and costs, while at the same time improving productivity, quality, and worker health and safety – sound impossible? Not so, says Wayne Maynard, C.S.P., C.P.E., ergonomics and tribology product director at the Liberty Mutual Research Institute for Safety. “Ergonomics in the workplace is good for both the worker and the employer,” states Maynard. “The goal is to obtain a good match between the worker and the job. In manual materials handling, ergonomics is designing the job or task to fit the worker.”

In its quest to improve job design and reduce work-related, manual materials handling injuries, the Liberty Mutual Research Institute for Safety has built a longstanding reputation for providing the research behind the know-how. From the early psychophysical studies to the later biomechanical investigations, the Institute’s scientific findings and methodologies have formed the basis for recommendations and assessment tools that help the practitioner determine how much is too much.

One of Liberty Mutual’s best-known, research-to-practice applications is the Liberty Mutual Manual Materials Handling Tables. This ergonomic assessment tool, based on the Snook and Ciriello Tables (see p. 4), enables practitioners to evaluate lifting, lowering, pushing, pulling, and carrying tasks with the primary goal of supporting ergonomic design interventions. The Tables also provide both the male and female population percentages capable of performing the tasks without overexertion. “The only difference between the Liberty Mutual Tables and the Snook and Ciriello Tables is the output,” explains Maynard. “Instead of getting an acceptable weight or force as the result, with the Liberty Mutual Tables, the practitioner begins with the weight or force that the worker may lift, lower, push, pull, or carry to determine the population percentage that is able to perform the task.” The tables are available for public use on the Research Institute website.

The Snook and Ciriello Tables also formed the basis of CompuTask™, which was developed by Liberty Mutual in the 1980s. This ergonomic assessment software program is widely used by Liberty Mutual field consultants to identify the risk factors associated with tasks involving high frequency and moderate weight. CompuTask offers the added benefit of an energy expenditure result with suggested maximum duration based on the NIOSH physiological guidelines. Further, it eliminates the need to manually select table values, thereby reducing human error. In 1990, the original CompuTask was revised and expanded to include three modules – manual materials handling analysis, the 1991 NIOSH Lifting Equation, and repetitive wrist motion. “We’ve had tremendous success with CompuTask,” says Maynard. “It truly provides an objective assessment of the task and reveals areas of risk. With this knowledge, we can help companies control costs through ergonomic recommendations for interventions that fit the task to the worker and ultimately reduce injuries.”
Developed using Research Institute findings, VidLiTeC™ enables our loss prevention consultants to conduct detailed analyses of manual materials handling tasks as they occur.

Advances in the Research Institute’s biomechanics research during the 1990s resulted in another assessment tool developed by Liberty Mutual. VidLiTeC™, short for Video-Based Lifting Technique Coding System, helps ergonomists and researchers evaluate lifting and lowering tasks involving lower frequencies and heavier weights. The program provides objective information to help companies design tasks to fit the worker. “The beauty of VidLiTeC is that, unlike other motion tracking software, it is straightforward to use in the workplace,” notes Maynard. “Simply put, we shoot a video, input height and weight estimations of the worker, and the weight of the item being lifted. From four select video frames – start, closest, highest, and end - we can compute the low back compression forces. The process takes only a few minutes.”

To illustrate the benefits of VidLiTeC, Maynard shares a Liberty Mutual loss prevention success story. The customer, a beer brewer and distributor, had experienced growth in product lines and facility expansion. This new growth also brought about an increase in material handling strain and sprain injuries as workers unloaded cases of empty bottles from pallets onto the bottle un-caser machine in-feed belt. Using VidLiTeC to assess the task, the program reported low-back L5/S1 disc compressive force exceeding 1,045 pounds as workers lifted 28 pounds of empty bottles and cardboard cases; however, the maximum disc compressive force limit is 770 pounds. The VidLiTeC evaluation also reported exceeding joint strength limits associated with this same task. Based on this objective information, the company decided to install scissor lifts that automatically lift the pallet, as it is unloaded. In the three years since the lifts were installed, there have been no other sprain and strain injuries from workers unloading pallets.

“In industry, a well-designed job can be both efficient and safe,” states Maynard. “Proper task evaluation and designing the job based on sound ergonomic principles is a win-win for all and is an approach that Liberty Mutual has long supported through its research and development efforts.”

Manual Materials Handling Guidelines

The following is a list of important considerations for designing jobs that involve manual materials handling:

Injuries – Any job that produces injuries is a good candidate for redesign.

Bending – Any task that begins or ends with the hands below knuckle height presents some degree of risk. The deeper the bending motion, the greater the physical stress on the low back. Frequent bending regardless of weight is not recommended.

Twisting – This motion puts uneven forces on the back thereby presenting additional physical stress. The greater the twist, the more physically stressful the task.

Reaching – The distance that a load is held away from the body greatly affects the forces on the back, shoulders, and arms. The farther the reach, the more physically stressful the task.

One-Handed Lifts – By nature, these tasks place uneven loads on the back and present a greater physical stress than two-handed lifts.

Hand-Holds – The inability to get a good grip on the load presents a greater physical stress.

Catching or Throwing Items – Any tasks involving catching or throwing items are physically stressful and, therefore, are good candidates for redesign.


Visit www.libertymutual.com/researchinstitute to access the Liberty Mutual Manual Materials Handling Tables.
Dear Readers,

It is with great pride that I present this issue of From Research to Reality, which chronicles the Research Institute’s rich history of manual materials handling research. For more than five decades, Liberty Mutual scientists have investigated this area, and for good reason. Manual materials handling tasks, which are present in practically all industries, account for more than a quarter of all compensable work injuries. Our scientific findings, translate into practical applications and recommendations that help countless companies minimize job risks and control costs. In this way, our manual materials handling research helps to fulfill Liberty Mutual’s longstanding commitment to help people live safer, more secure lives.

We hope you find this issue interesting and valuable, and as always, we welcome your feedback.

Y. Ian Noy, Ph.D.
Vice President and Director

From Research to RealityTM is a publication of the Liberty Mutual Research Institute for Safety, an internationally recognized occupational safety and health research facility. Through its broad-based investigations, the Institute seeks to advance scientific, business-relevant knowledge in workplace and highway safety and work disability. The Institute’s findings are published in the open, peer-reviewed literature and often serve as the basis for recommendations, guidelines, and interventions used by industry to help reduce workplace injury and related disability.

Readers may reprint any item from this newsletter with specific acknowledgement of the source. For more information about our publications, programs, or activities, or to be added to our mailing list, please visit www.libertymutualgroup.com/researchinstitute.

Telephone: 1-508-497-0257
E-mail: researchinstitute@libertymutual.com