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Manual Lifting: Historical Sources of Current Standards Regarding Acceptable Weights of Lift

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FOREWORD

Low back pain was one of the major concerns of Bernardino Ramazzini, "the founder of occupational medicine," when he published his works in the late 1600's. Throughout this century, the manual handling of objects has accounted for 20-25% of all occupational injuries and has exceeded motor vehicle accidents (and all other single causes) as a cause of lost work time and associated monetary costs.

Today it is recognized that the most effective way to control back injuries is through proper design and evaluation of the workplace. Instructions to "lift with your legs and not your back" and "keep your back straight" are of limited value without workplace controls. Employers should know that it is also of little value to tell workers to "ask for help when you feel you need it" because a dangerous lift may "appear" or "feel" acceptable to the worker until an injury has occurred.

HISTORICAL DEVELOPMENT OF MANUAL LIFTING GUIDELINES AND STANDARDS

During World War II, the Bureau of Labor Standards of the U.S. Department of Labor responded to the high volume of manual lifting and materials handling injuries that cut deeply into the war production effort by issuing "**Bulletin No. 11 - A Guide to the Prevention of Weight Lifting Injuries**." This guide recommended a maximum limit (for compact objects) of 50 pounds for male workers and 25 pounds for female workers. These limits were published by the National Safety Council, and others, as the prevailing standard for the next 25 years.

During the early 1960's, however, a renaissance fed by the increasing application of science to low back pain etiology began to take place in manual lifting research. A number of studies were based on the psychophysical approach, or the research method that relies on the subjective responses of test subjects under controlled conditions. The scientific literature also began to speak of back physiology, human kinetics, and the biomechanics of lifting. Epidemiological studies based on statistical procedures identified factors and activities that were linked with the onset of low back pain. High-risk material handling activities that were identified include lifting, twisting, bending, reaching, and slipping (both with and without falling).

A 1961 investigation of lifting and carrying by the Swiss Accident Insurance Institute was published by the International Occupational Safety and Health Information Center (CIS) in 1962 as "**CIS Information Sheet No. 3**." Weight limits for occasional below-the-waist lifting of compact loads recommended by the CIS report were based on biomechanical criteria related to the amount of stress imposed upon the spinal discs. The CIS basic weight limits ranged form 33-55 pounds for males and 22-33 pounds for females depending on age.

In 1964, the International Labor Organization (ILO) concluded a study "**On the Maximum**

Permissible Weight To Be Carried By One Worker" based on individual physiological capacities. The ranges of weights recommended by the ILO were 33-88 pounds for males and 26-44 pounds for females depending on age.

Snook and Irvine pointed out that the ILO recommendations applied to "workers employed in operations requiring lifting and carrying of weights." Such workers would have a higher level of fitness and training compared with the general population; thus, application of the ILO limits should be restricted. Additionally, the ILO recommendations were to be applied to workers of "normal constitution." However, Damon, et al have pointed out that designing a task to protect the 50th percentile (the "normal" or "average" person) leaves 50 percent of the population unprotected.

In 1965, The Bureau of Labor Standards declared its Bulletin No. 11 obsolete with the publication of **"Bulletin 110 – Teach Them to Lift."** This publication recommended the new ILO limits, but (like Snook and Irvine) noted reservations with respect to application.

In l967, Snook and Irvine published "**Maximum Acceptable Weight of Lift**," which discussed the merits and limitations of earlier studies and presented the results of their own research. This psychophysical study asked subjects to subjectively determine the maximum weight that could be lifted comfortably every 15 minutes without straining. Their results indicated that 50 pounds is the maximum weight of a compact object that should be lifted by unselected, adult male workers. According to this study, with proper personnel selection, this maximum weight limit could approach 75-80 pounds for lifts from floor level to knuckle height, and 65-75 pounds for lifts above knuckle height.

The International Labor Office published "**Kinetic Methods of Manual Handling in Industry**" in 1967. This biomechanical study discussed the dynamic use of body weight during the lifting process. The publication stated that "if a 25-kilogram weight (55 pounds) is to be lifted straight upwards with the muscles of the lower limbs, the pressure on the point of the fourth and fifth lumbar vertebrae is approximately 150 kilograms (330 pounds); if lifting is done with a slightly bent back, the pressure will be 300 kilograms (66l pounds); and if the lifting is done with a full bend, the pressure will be as much as 550 kilograms (1212 pounds)." This information only awaited a deeper understanding of the pressures likely to cause spinal injury for its full import to be realized.

In l968, Snook and Irvine published "**Maximum Frequency of Lift Acceptable to Male Industrial Workers**." This study, like their 1967 publication, was based on psychophysical criteria. The subjects were asked to imagine that they were working a normal eight hour shift without becoming tired, weakened, overheated, or out of breath and that they were being paid for the number of lifts made. In this study, male industrial workers selected a mean work load of 244 ft-lbs/min. while lifting objects weighing 35 pounds from floor to knuckle height, and 413 ft-lbs/min., when lifting the same weight from knuckle to shoulder height. Corresponding workloads when lifting 50 pounds were 317 and 454 ft-lbs/min., respectively.

The work of Snook and Irvine formed the basis for a 1970 publication by the American Industrial Hygiene Association entitled "**Ergonomics Guide to Manual Lifting**" that was recommended for use by general industry as an aid in the evaluation of work situations involving manual lifting tasks.

Tichauer's 1971 publication, "**A Pilot Study of the Biomechanics of Lifting in Simulated Industrial Work Situations**," showed that the severity of a lifting task can not be measured by the weight lifted but that torque (the product of the weight and its distance from point of application) is the true index of task severity. Tichauer's article also contained an excellent bibliography of previous work in the field of biomechanics.

As the l970's proceeded, increased emphasis was given to the study of back physiology, biomechanics, and the full range of factors influencing the risk of injury during the lifting task. In l975, Chaffin and Ayoub reported results of work conducted by the National Institute for Occupational Safety and Health (NIOSH) that defined several broad components of the lifting task related to the risk of back injury. These

components were classified into four categories: (l) worker characteristics, (2) characteristics of the material or object to be lifted, (3) task characteristics, and (4) work practices.

Important worker characteristics include age, sex, anthropometry, coordination, degree of formal training in manual material handling, work experience, general health, and general level of physical activity.

Important characteristics of the object being lifted include weight, dimensions, center of gravity, ease of grasp, and stability of load.

Important task characteristics include workplace geometry, lift frequency, duration of lift, pace, complexity of lift (load manipulation requirements), and environmental factors such as temperature, humidity, lighting, and traction.

Important work practices include lifting techniques, the freedom of the individual worker to control the pace, use of teamwork, work/rest schedule, mechanical lifting aids, and the use of personal protective equipment.

In 1976, Chaffin and Ayoub (**Professional Safety**, 1976) offered the results of their studies regarding maximum acceptable weights of lift for male and female industrial workers. Their recommendations showed the increasing tendency to consider the concept of "load moments" in the analysis of lifting tasks as illustrated by the following quotation: "If the workplace requires a 20-pound object to be 20 inches horizontally displaced from the hips during a lift, a load moment of 400 pound-inches will result at the hips. This would probably result in an acceptable force distribution in the spinal column of most men, but if displaced 30 inches, the resulting 600 pound-inches will exceed the tolerable levels for many men and women." The study recommended the workplace should be designed to keep the load center close to the body "especially if the load is more than 35 pounds." This work also contained an excellent updated bibliography.

Results of the Chaffin and Ayoub study indicated that the maximum acceptable weight that can be lifted by 90 percent of male industrial workers (from floor to knuckle height) is 37 pounds while 76 pounds would be acceptable for only 10 percent of the male workforce. Corresponding weights for female workers were 19 and 46 pounds, respectively. Mean weight acceptable to 50 percent of workers would be 53 pounds for males and 33 pounds for females.

Chaffin and Ayoub's corresponding maximum acceptable weights for knuckle to shoulder height lifts would be 40 pounds acceptable to 90 percent, 55 pounds acceptable to 50 percent, and 69 pounds acceptable to 10 percent of the male workforce. The respective weight limits for women were 23 pounds, 27 pounds, and 31 pounds.

Also in 1976, an international symposium entitled "**Safety in Materials Handling**" was held at the State University of New York at Buffalo. The proceedings of the symposium (published by NIOSH) contained an excellent summary of the state-of-the-art in manual materials handling at the time of publication.

In 1980, as published in ***Professional Safety***, Stover Snook (with Liberty Mutual) developed a series of 10 tables for evaluating manual handling tasks using seven previous studies of lifting, lowering, pushing, pulling, carrying, and walking. Six of the studies utilized the psychophysical methodology, which is the relationship between human sensations and their physical stimuli, using the theory that the strength of the sensation is directly related to the intensity of the physical stimulus.

Applying this methodology to manual lifting, the individual worker determined their maximum acceptable weight of lift based on their own sense of the various strains associated with various manual handling tasks. For a given time period and task, the worker determined the weight that allowed them to work as hard as they could, but without straining themselves, becoming unusually tired, weakened, overheated, or out of breath.

Also in 1980, advancing the ergonomics approach, the Materials Research Unit of the University of Surrey (England) published "**Force Limits in Manual Work**." This work focused on the close relationship between the forces acting on the lower back and the pressures generated in the abdominal cavity and noted that workers that frequently must tolerate abdominal pressures in excess of 100 mm Hg also have a significantly high incidence of back pain. This report presents maximum recommended force limits for one-handed and two-handed lifts when standing, squatting, sitting, and when kneeling on one knee.

By the early 1980's, the four separate and independent approaches to investigating the causes of back injury and pain (psychophysical, epidemiological, physiological, and biomechanical) had converged in their findings. In 1981 the National Institute for Occupational Safety and Health (NIOSH) published its "**Work Practices Guide for Manual Lifting"** (WPG, 1981)**.** This landmark document provided a unified basis for understanding the factors controlling risks of worker injuries in the performance of materials handling tasks. The recommendations of this guide were based on the combined results of investigations made by scientists, engineers, and physicians, as well as on empirical observations made at "the job site."

An excellent review of the **NIOSH Guide** was published in the National Safety Council's National Safety News in October of 1982. In 1983, the Council explained the NIOSH guidelines in an educational film titled "**Back Injury Prevention Through Ergonomics**." The next revision (9th or 1988 edition) of the National Safety Council's Accident Prevention Manual for Industrial Operations also explained practical applications of the NIOSH guidelines.

The 1981 lifting guide (WPG) resulted in two *calculated lifting limits* for a particular lifting task. The lower of the two limits was designated the **Action Limit** (AL). The upper limit was defined as three times the AL and was designated the **Maximum Permissible Limit** (MPL). A lifting task was evaluated by comparing the weight lifted with the two calculated limits for that task (AL and MPL). Lifting of weights below the AL was considered to be associated with an acceptably low risk of injury for most industrial workers. The maximum possible AL, given ideal lifting conditions, was 90 pounds.

For weights of lift above the calculated AL, some "action" was required; and the preferred action was to utilize engineering controls (redesign of the lifting task) to eliminate manual lifting above the AL. Where engineering controls were not reasonably feasible to control lifting hazards, management could chose to utilize administrative controls to protect workers in lifting weights above the AL, but below the MPL. In such cases, only rigorous administrative controls such as, medical monitoring, strength testing, and special training were considered acceptable to qualify individual workers. Lifting of weights greater than the MPL was considered unreasonably dangerous for all workers regardless of strength or training.

Since its publication in 1981, the **NIOSH Guide** has been accepted by virtually every authoritative industrial safety publication as **THE** current authority for the general evaluation of workplace lifting hazards. The **NIOSH Guide** provided a tool for managers to use in determining acceptable weights of lift as well as providing criteria for administrative and engineering control of lifting hazards.

In 1988, **ASTM** published its **Standard Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities (ASTM F-1166)**, that contained a table of lifting limits (design weight limits) and also addressed guidelines for lifting frequency, load size, carrying limits, push and pull force limits, as well as guidelines for handholds. This standard was updated in 2007.

As a result of NIOSH convening a group of experts to review the current literature on lifting to revise the WPG, three documents were published between 1991 and 1994 to include: an ***updated NTIS literature review*** (LR, 1991), a ***revised NIOSH equation journal article*** (RE, 1993), and a detailed ***revised equation Applications Manual*** (REAM, 1994).

The *literature review* (LR, 1991) contains updated information on the physiological, biomechanical, psychophysical, and epidemiological aspects of manual lifting. This formed the basis used by the ad hoc committee of experts to recommend criteria for defining the lifting capacity of healthy workers. The literature review does not contain the revised lifting equation. However, the revised equation was distributed in 1991 by NIOSH staff to attendees at an Ann Arbor, Michigan conference entitled *A National Strategy for Musculoskeletal Injury Prevention -- Implementation Issues and Research Needs*.

Also in 1991, as published in ***Ergonomics***, Snook reviewed four new manual handling research studies, all utilizing the psychophysical methodology, integrated the results of these studies with the previous data, and revised the 10 tables based on the results.

The NIOSH *revised equation* (RE, 1993) provided a more widespread distribution of the revised equation, explains the biomechanical, physiological, and psychophysical criterion used for its development, and provides a description of the derivation of its individual components. The article points out the need for appropriate studies to determine the effect of the recommended methods on the injury morbidity associated with manual materials handling, particularly two-handed lifting tasks.

The NIOSH published *Applications Manual* (REAM, 1994) explains how to apply the revised lifting equation through the use of examples including step-by-step instructions. A copy of the *journal article* (RE, 1993) is included in the appendix of the *Applications Manual*.

While the load constant for the 1981 WPG was 90 pounds, the load constant for the revised equation was 51 pounds. However, these load constants are substantially similar in consideration that lifting a weight of 51 pounds at 10 inches forward of the midpoint between the ankles results in about the same compressive force on the spine as lifting a weight of 90 pounds at 6 inches forward of the midpoint between the ankles. That is, largely due to anthropometric considerations (actual body dimensions), the minimum distance of a lift in front of the body was merely increased from 6 to 10 inches.

The *revised lifting equation* results in two calculated values. The first is the **Recommended Weight Limit** (RWL) that corresponds to the AL in terms of acceptable weight of lift. The maximum possible RWL is 51 pounds. The second value is the **Lifting Index** (LI) that is defined as the actual weight lifted divided by the RWL. The LI gives a relative indication of the risk of injury associated with various lifting tasks. Available data does not allow prediction of the magnitude of risk for any individual or the exact percent of the work population who would be at an elevated risk for back injury as the LI increases above 1.0. The NIOSH perspective is that it is likely that tasks with a LI >1.0 pose an increased risk of lifting related injury. Hence the goal should be to design all lifting jobs for LI of 1.0 or less.

In 2004, the Liberty Mutual Research Institute for Safety published its **Liberty Mutual Manual Materials Handling Guidelines**, updating the manual material handling tables originally published by Snook in 1978, and by Snook and Ciriello in 1991.

While the previously published (1978, 1980, 1991) "Snook Tables" provided an indication of the *maximum acceptable weights* and *forces* for 10, 25, 50, 75, and 90 percent of the male and female populations, the new 2004 "Liberty Mutual Manual Materials Handling Tables" (Liberty Mutual Tables) provide both the male and female population percentages capable of performing manual material handling tasks without over exertion, rather than maximum acceptable weights and forces. This manual material handling analysis tool can be used to perform ergonomic assessments of lifting, lowering, pushing, pulling, and carrying tasks with the primary goal of supporting ergonomic design interventions.

The population percentages presented in the Liberty Mutual Tables are based on weights selected by subjects in the laboratory working as hard as they could without straining themselves, or without becoming unusually tired, weakened,

overheated, or out of breath. The Liberty Mutual Tables may be used for designing manual handling tasks with physical requirements such that as many workers as possible can perform such tasks without risk of injury.

At the same time, Liberty Mutual offers the following caution on using the tables: Tasks should not be evaluated based solely on population percentages. Other important considerations include: historical injuries, and any task involving bending, twisting, reaching, one-handed-lifting, questionable handholds (the ability to get a good grip), and catching or throwing activities.

In 2003, the American Bureau of Shipping published its **Guidance Notes for the Application of Ergonomics to Marine Systems**, providing guidelines that recognize that factors that affect a person's ability to safely and effectively perform materials handling tasks include the design of the task, the form of the material handled, the design of the work area, the availability of lifting devices, and the physical/physiological characteristics of the personnel themselves.

The ABS guidelines address one person versus two-person lifting and carrying, mechanical assisted lifting, and present tables that outline design weight limits for lifting as well as multipliers that may be required to reduce standard weight limits based on, among others, age, asymmetrical lifting, handholds, and load size.

In 2005, the American Conference of Governmental Hygienists (ACGIH) published its **TLV for Lifting**. ACGIH Lifting TLVs represent recommended workplace lifting conditions under which it is believed nearly all workers may be repeatedly exposed, day after day, without developing work-related low back and shoulder disorders associated with repetitive lifting tasks.

ACGIH Lifting TLVs consist of three tables with weight limits for two-handed mono-lifting tasks within 30 degrees of the sagitall (neutral forward) plane. Mono-lifting tasks are those in which the loads are similar and repeated throughout the day.

For example, Table 1 lists weight limits associated with lifting tasks of short duration involving $\leq$ 2 hours per day with $\leq$ 60 lifts per hour, or > 2 hours per day with $\leq$ 12 lifts per hour (which would include single lifts).

The ACGIH TLV for Lifting also contains the caution that in the presence of any factor or working condition listed below, professional judgment should be used to reduce weight limits below those recommended in the TLVs:

- High frequency lifting >360 lifts per hour.
- Extended work shifts: lifting performed for longer than 8 hours per day.
- High asymmetry: lifting more than 30 degrees away from the sagittal plane.
- Rapid lifting motions and motions with twisting (e.g. from side to side).
- One-handed lifting.
- Constrained lower body posture, such as lifting while seated or kneeling.
- High heat and humidity.
- Lifting unstable objects (e.g., liquids with shifting center of mass or lack of coordination or equal sharing in multi-person lifts).
- Poor hand coupling: lack of handles, cutouts, or other grasping points.
- Unstable footing (e.g. inability to support the body with both feet while standing)

For <u>further information</u>, see the following Nelson & Associates Fact Sheets:

> "Manual Lifting: The NIOSH Work Practices Guide for Manual Lifting - Determining Acceptable Weights of Lift" (Effective from March 1981 to July 1994)."
>
> "Manual Lifting: The Revised NIOSH Lifting Equation for Evaluating Acceptable Weights for Manual Lifting (Effective July 1994)"
>
> "Manual Lifting: Training Programs in Manual Materials Handling"
>
> "Manual Lifting: Product Design and Labeling"

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