Manual Materials Handling Research

Since the late ’70s, Liberty Mutual Loss Prevention has been analyzing and evaluating lifting, lowering, pushing, pulling, and carrying tasks using psychophysical tables. Consultants initially performed these analyses using manual tables. Some have referred to these as “Snook Tables” (Snook, 1978) and later “Snook and Ciriello Tables” (Snook and Ciriello, 1991). Tables used by the Loss Prevention department were different from those in the published papers. Our tables determined the male and female population percentages able to perform the task while the published articles provided maximum acceptable weights and forces for 10, 25, 50, 75, 90 percent of the male and female population. In the mid 1980s a software program called CompuTask™ was developed by Liberty Mutual and based on research from the Liberty Mutual Research Institute for Safety. The repetitive wrist motion research was added in the mid 90s and CompuTask™ was changed to CompuTask2™ at that time.

This Reference Note will provide some background of the manual handling research performed at the Liberty Mutual Research Institute for Safety and how this research is used to improve safety of manual handling tasks performed in the real world.

Background

Eleven manual material handling (MMH) experiments form the basis of the maximum weights and forces acceptable to male and female workers comprehensive guideline (Snook and Ciriello, 1991). This guideline used a psychophysical methodology, with measurements of oxygen consumption, heart rate, and anthropometric characteristics. Essentially, the subject is given control of either the weight or force variable. All other task variables such as frequency, size, height, distance, etc., are controlled by the experimenter. The subject then monitors his or her own feelings of exertion or fatigue, and adjusts the weight or force of the object accordingly. Details of the experimental designs used in the studies are found in the individual papers (Ciriello and Snook 1983, Ciriello *et al.* 1990, Ciriello *et al.* 1993). The main features of the basic design, however, are given below.

Realistic tasks

The experimental tasks were made as realistic as possible. For example, lifting tasks were dynamic lifts through a given vertical distance. Pushing and pulling tasks were dynamic pushes through a given horizontal distance. Test sessions lasted approximately 4 hours. Each test session usually consisted of five different 40 minute tasks, separated by 10 minute breaks. When testing for the effects of duration, the same task was performed for 4 hours with a 20 minute break after 100 minutes. Groups of three subjects participated in at least two test sessions per week for a minimum of ten weeks.

Apparatus

During lifting, lowering, and carrying tasks, subjects handled industrial tote boxes or cardboard boxes. The boxes varied in length (the distance between the hands) and width (the distance away from the body). When handles were used, they were located mid-way in the width dimension. Each subject varied the weight of the box by adding or subtracting loose shot with a small scoop. Welding rod was used in the larger boxes. In an attempt to minimize visual cues, each box contained a false bottom. The subjects were aware of the false bottom, but never knew how much shot or welding rod it contained. The amount of weight in the false bottom was randomly varied.

Figure 1. Lifting/lowering platforms

A special device with a rapidly-moving shelf was used to automatically lower the box after each lift, or to raise the box after each lowering task. When the box was removed from the shelf by the subject, the shelf quickly moved to a new, predetermined position in time for the subject to place the box on the shelf. The box was slid off the shelf, lifted (or lowered) clear of the moving shelf, and then slid back onto the shelf. In most cases, the lifts and lowers were not truly symmetrical since some degree of body twisting was involved. When the box was replaced on the shelf, the shelf returned to its original position.

The starting and stopping points of the shelf were adjustable. Figures 1-3 illustrate the lift/lower platform design and a subject performing low lifting tasks and extended reach lifting tasks.

Figure 2. Low lifting

Figure 3. Pushing example

Pushing and pulling tasks were simulated on a specially constructed treadmill. The treadmill was powered by the subject as he or she pushed or pulled against a stationary bar. A load cell on the stationary bar measured the horizontal force being exerted. The subject controlled the resistance of the treadmill belt by varying the amount of electric current flowing into a magnetic particle brake geared to the rear drum of the treadmill. All subject controls were devoid of visual cues. Figure 4. Illustrates a subject performing a pushing task on the treadmill.

Figure 4. Extended reach lifting

Most experiments were conducted in a 3.9 meters x 2.8 meters x 3.0 meters environmental chamber. The dry bulb temperature was maintained at a moderated 21.0ºC; relative humidity was 45%.

Industrial workers

Subjects were second-shift (evening shift) workers from local industry. They were all given a medical examination prior to their participation in the experiments to ensure that they were in relatively good health. A battery of 41 anthropometric measurements was taken for each subject. Clothing was controlled by providing surgical scrub suits for all subjects. Safety shoes with neolite heels and soles were also provided to control for variations in traction during pushing and pulling tasks. Heart rate was monitored continuously by radio telemetry for each subject. Instantaneous measurements of steady state oxygen consumption were obtained after subjects had selected the maximum acceptable weight or force.

Procedure

Subjects were instructed to work on an incentive basis, working as hard as they could without straining themselves, or without becoming unusually tired, weakened overheated, or out of breath. Four or five days of training sessions were provided to allow subjects to gain experience at monitoring their own feelings and adjusting object weight or force. Subjects began with moderate-frequency, short-duration tasks and gradually conditioned themselves to the faster, longer tasks.

New subjects tended to accept the initial weight of the object that was given to them. Therefore, they were encouraged to make adjustments in the weight by starting them with a very light or a very heavy weight. To overcome adaptation effects, each manual handling task was broken up into two 20 minute segments; one segment with a heavy initial weight and the other segment with a light initial weight. There was no rest period between the two segments. If the results of the first segment were within 15% of the second segment, the average of the two results was recorded. Otherwise, the results were discarded and the test re-run at another time. Similar procedures were used when testing for the effects of duration, except that eleven 20 minute segments were used with a 20 minute break after the fifth segment (Ciriello *et al.* 1990).

Each of the eleven experiments included two types of tasks: criterion tasks and variation tasks. There were a total of seven criterion tasks (two lifting, two lowering, one pushing, one pulling, and one carrying). Each experiment investigated different variations in task frequency, height, distance, and box size. Since it was impractical to run every subject on every possible variation task, the percentage difference from the criterion task was used to develop an adjusted mean for each variation task. (The criterion and variation tasks were performed by the same groups of subjects.) The standard deviation for each variation task was determined from the adjusted mean and the criterion task coefficient of variation. The mean and standard deviation for each criterion and variation task were used with the normal distribution to determine the maximum weights and forces acceptable to 10, 25, 50, 75 and 90% of the industrial population. These data are presented in 9 tables of maximum acceptable weights and forces (Snook and Ciriello, 1991) and form the basis of the software program CompuTask2™. Further experimentation has checked the validity of some assumptions made in the 1991 guideline (Ciriello et al., 1999a, Ciriello et al., 2001a, Ciriello, 2001). Future experimentation will be guided by our recently published comprehensive MMH surveys (Ciriello and Snook, 1999, Ciriello et al., 1999b).

The above research provides us with a method to analyze and evaluate manual handling tasks that contribute to musculoskeletal injuries including low back disability. The population percentages or outputs provided by CompuTask2™ provide an assessment of risk before and after ergonomic interventions are implemented. Outputs from CompuTask2™ can be used to help customers identify cost-effective and practical solutions that offer the highest degree of control.

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