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Applied Ergonomics 38 (2007) 1–5

APPLIED ERGONOMICS

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The effects of container size, frequency and extended horizontal reach on maximum acceptable weights of lifting for female industrial workers

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Received 30 March 2005; accepted 3 February 2006

Abstract

In the development of our present manual materials handling (MMH) guidelines (Snook, S.H., Ciriello, V.M., 1991. The design of manual tasks: revised tables of maximum acceptable weights and forces. Ergonomics 34, 1197–1213), the assumption was made that the effects of frequency on maximum acceptable weights (MAWs) of lifting with a large box (hand distance, 38 cm from chest) were similar to that of lifting with a small box (hand distance, 17 cm from chest). The first purpose of the present experiment was to investigate this assumption with female industrial workers. The second purpose was to study the effects of extended horizontal reach lifting (hand distance, 44.6 cm from chest) on MAWs as a confirmation of the results of a previous studies on this variable with males (Ciriello, V.M., Snook, S.H., Hughes, G.J., 1993. Further studies of psychophysically determined maximum acceptable weights and forces. Hum. Factors 35(1), 175–186; Ciriello, V.M., 2003. The effects of box size, frequency, and extended horizontal reach on maximum acceptable weights of lifting. Int. J. Ind. Ergon. 32, 115–120). Lastly, we studied the effects of high frequency (20 lifts/min) on MAWs of lifting. Ten female industrial workers performed 15 variations of lifting using our psychophysical methodology whereby the subjects were asked to select a workload they could sustain for 8 h without "straining themselves or without becoming unusually tired weakened, overheated or out of breath". The results confirmed that MAWs of lifting with the large box was significantly effected by frequency. The frequency factor pattern in this study was similar to the frequency pattern from a previous study using the small box (Ciriello, V.M., Snook, S.H., 1983. A study of size distance height, and frequency effects on manual handling tasks. Hum. Factors 25(5), 473–483) for all fast frequencies down to one lift every 2 min with deviations of 7%, 15%, and 13% for the one lift every 5 and 30 min tasks and the one lift in 8 h task, respectively. The effects of lifting with an extended horizontal reach decreased MAW 22% and 18% for the mid and center lift and the effects of the 20 lifts/min frequency resulted in a MAW that was 47% of a 1 lift/min MAW. Incorporating these results in future guidelines should improve the design of MMH tasks for female workers.

Keywords: Psychophysics; Manual materials handling; Box size

1. Introduction

The most frequent (36% of all claims) and costly (35% of total cost) category of compensable loss in the USA is manual materials handling (MMH) (Leamon and Murphy, 1994; Murphy et al., 1996; Dempsey and Hashemi, 1999). MMH is also associated with the largest proportion (63–70%) of compensable low back disability claims (Snook et al., 1978; Bigos et al., 1986; Murphy and Courtney, 2000). A small percentage of the most costly low back claims (10%) are reported to be responsible for a large percentage of the total cost of low back claims (86%) (Hashemi et al., 1997). In this same study, the authors reported days of disability for low back pain to be skewed to long durations with a average and median of 303 and 39 days, respectively. To control these losses, ergonomics redesign of MMH tasks has the two fold advantage of accommodating the workplace to a high percentage of the industrial population with and without low back disability (Snook et al., 1978; Benson, 1986, 1987; Snook, 1987; Ciriello and Snook, 1999; Ciriello et al., 1999). Acceptable loads and limits in MMH have been analyzed and established using a wide spectrum of techniques including

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0003-6870/$ - see front matter
doi:10.1016/j.apergo.2006.02.001

physiological, biomechanical, subjective, observational, focus groups, psychophysical, postural analysis and a combination of the above (Kemper et al., 1990; Kivi and Mattila, 1991; Waikar et al., 1991; Burdorf et al., 1992; Waters et al., 1993; de Looze et al., 1994; Winkel and Mathiassen, 1994; Van der Beek et al., 2005; Bust et al., 2005).

In this laboratory, maximum acceptable weights (MAWs) and forces have been determined using the psychophysical technique (Snook and Ciriello, 1991) and used extensively to redesign work places (Benson, 1986, 1987; Ciriello and Snook, 1999; Ciriello et al., 1999). Our surveys have indicated that lifting comprises 40% of all MMH tasks which encompass lifting, lowering, pushing, pulling, and carrying (Ciriello et al., 1999) and thus demands attention to refinement. In our present MMH guideline (Snook and Ciriello, 1991, p. 1211), we reviewed the assumptions that were made in the development of this guideline. These assumptions were necessary to fill in specific variable effects that had not yet been investigated. One of the variable effects stated that the frequency effects on MAWs of lifting a large box with a hand distance of 38 cm from the chest were similar to that of lifting a small box with a hand distance of 17 cm from the chest (Ciriello and Snook, 1983). The first purpose of this experiment was to investigate this assumption with female industrial workers. The second purpose was to study the effects of an extended horizontal reach on MAWs of lifting and to compare the results with previous studies with males (Ciriello et al., 1993; Ciriello, 2003). Lastly, we studied the effects of a high frequency (20 lifts/min) on MAWs of lifting, a frequency not previously studied in this laboratory with females. With the above information, a more precise estimate of MAWs for the female industrial population can be determined.

2. Method

2.1. Subjects

Ten female industrial workers, who were experienced in MMH, were recruited by local advertisement. They were examined by a nurse practitioner to ensure that they had no serious cardiovascular problems and had not experienced previous significant low back pain or musculoskeletal problems of the extremities. Before participation, written informed consent approved by our Institutional Review Committee was obtained from the subjects.

Shoulder, elbow and knuckle heights were taken to set the ranges for the lifting tasks to the individual's anthropometrics. These measurements along with stature were also compared with military and industrial populations to ensure similarity with our subjects (Snook and Ciriello, 1974; Ciriello et al., 1990; Eastman Kodak Co., 1986; Gordon et al., 1989; Marras and Kim, 1993). The comparisons of the above measurements yielded a median difference of 0.6% (range 0.2–4.6%). The subjects' mean (SD) values for age, weight, stature, shoulder height, elbow height, and knuckle height were 42.9 (11.2) years, 69.6 (10.8) kg, 161.8 (3.8) cm, 133.7 (4.1) cm, 102.8 (3.3) cm, and 73.3 (3.3) cm, respectively.

2.2. MMH tasks

Subjects performed 15 variations of lifting using two plastic boxes with external wooden handles. The external handles are 17.8 cm in length and 4.2 cm thickness and devoid of sharp edges. The small box represented a common small industrial tote box with the following dimensions; width, 33.4 cm, length, 56.2 cm, and depth, 16.0 cm. This box had also been used as a criterion box in previous studies conducted in this laboratory (Snook and Ciriello, 1991). The large box represented an extremely large industrial box with the following dimensions; width, 76.1 cm, length, 56.5 cm, and depth, 22.0 cm. The width represents the box distance in the plane away from the body and the length represents the distance between handles. The handles were placed midway in the width dimension. The handle placement enforced a minimum horizontal hand distance of 17 and 38 cm from the chest for the small and large box, respectively.

Lifting tasks were performed on pneumatically activated shelves that automatically moved to a specified vertical location and then returned the box to the original location. At the beginning of the lift, the subjects slid the boxes off the shelf and the shelf moved to the specified height. At the end of the lift, the subjects slid the boxes back on to the shelf. Subjects were deterred from lifting the boxes straight up in a vertical plane by being asked to imagine a rack of shelves above or below the box to be lifted. In most cases, this necessitated some degree of trunk twisting during lifting, which was not controlled or quantified.

Lifts had vertical distances of 51 cm and were studied in the middle of three ranges: between floor level and knuckle height (low lift), between 25.5 cm above and below knuckle height (mid lift), and between knuckle height and shoulder height (center lift). Low lifting with the large box was performed at frequencies of one lift every 5 s, 9 s, 14 s, 1 m, 2 m, 5 m, 30 m, and 8 h. The low, mid, and center lifting tasks with the small box were performed close to the body at 1 lift/min. In addition, the extended horizontal reach lifts were performed in the mid and center ranges with the small box at frequencies of one lift every 14 s and 1 min. The mid lift with the frequency of 20 lifts/min was performed close to the body.

The extended horizontal reach lift involved lifting with arms fully extended in front of the body. To enforce this posture, a wooden barrier was placed in front of the feet and a clear plexiglass barrier (26 cm wide × 229 cm high) was placed between the subject and the box. The plexiglass barrier prevented moving the box toward the body, and the wooden barrier prevented moving the feet closer to the box. This approach required lifting with a horizontal hand distance of 44.6 cm between the hands and the front of the body as measured at the chest. Subjects reached around