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Effects of carrying methods and box handles on two-person team carrying capacity for females

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ABSTRACT

This study used a psychophysical approach to examine the effects of carrying methods and the presence or absence of box handles on the maximum acceptable weight carried and resulting responses (heart rate and rating of perceived exertion) in a two-person carrying task. After training, 16 female subjects performed a two-person carrying task at knuckle height for an 8-h work period. Each subject performed 4 different carrying combinations two times. The independent variables were carrying methods (parallel and tandem walking) and box handles (with and without handles). For comparison with two-person carrying, the subjects also performed one-person carrying. The results showed that the maximum acceptable weight carried (MAWC), heart rate (HR), and rating of perceived exertion (RPE) were significantly affected by the presence of box handles. However, the subjects' MAWC, HR, and RPE values were not significantly influenced by the carrying methods. The test–retest reliability of the psychophysical approach was 0.945. The carrying efficiency of two-person carrying was 96.2% of the one-person carrying method. In general, the use of box with handles allows the subjects to carry a higher MAWC (with lower HR and RPE) compared to carrying boxes without handles.

1. Introduction

Manual materials handling (MMH) tasks have attracted substantial research interest for many years because they are one of the major contributors for musculoskeletal disorders, especially lower back pain. Previous studies (Ayoub and Mital, 1989; Chaffin and Andersson, 1991; Wu and Hsu, 1993; Genaidy et al., 1994; Wu, 1997; Dempsey, 1998; Li et al., 2009) reported that such injuries are mainly caused by overexertion, repetitive and prolonged task duration, or awkward working posture while performing MMH tasks. Therefore, the control of MMH-related injuries is a very important issue for employees, employers and society in general (Wu et al., 1993; Wu, 2000).

To control MMH-related injuries, the psychophysical method (Snook and Irvine, 1967) is one of the most widely accepted approaches utilized to investigate human capacity in MMH tasks (Snook, 1978; Snook and Ciriello, 1991; Waters et al., 1993; Lee et al., 1995; Ciriello and Snook, 1999; Wu, 2003; Ciriello, 2007). However, many of these studies focused only on individual MMH tasks rather than manual handling tasks performed by team. But in practice, there are many MMH tasks in manufacturing and service industries, agriculture and the military that require two or more people to handle heavy or large items (Johnson and Lewis, 1989; Sharp et al., 1993). In addition, working in team of two or more may enable individuals with less strength to perform tasks they could not execute alone (Sharp et al., 1995). Therefore, further study to understand the relationship between individual and team lifting capacity is important.

Ingham et al. (1974) first studied collective group performance in a rope pulling task, and subsequently team lifting/carrying studies using different approaches have been conducted by many ergonomists. Some scholars have studied the efficiency of team lifting strength, including isometric, dynamic, and isoinertial lifting in teams of two or more people (Karwowski and Mital, 1986; Karwowski and Pongpatanasuegsa, 1988; Karwowski, 1988; Sharp et al., 1993, 1997; Lee, 2004). Other scholars have studied the efficiency of psychophysical team lifting capacity (Fox, 1982; Johnson and Lewis, 1989; Sharp et al., 1995; Lee and Lee, 2001; Wu and Lin, 2005a,b). In general, these studies have concluded that the maximum lifting strength/capacity of a team is less than the combined maximum lifting strength/capacity of the individual team members (Dennis and Barrett, 2003).

In addition, some previous studies have been conducted to examine the effect of worker or load variables on the spinal load during two-person team lifting. With the worker variable, Marras et al. (1999) and Dennis and Barrett (2002) examined the effect of

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height-matched teams on spinal loads, Lee and Lee (2001) and Dennis and Barrett (2003) investigated the effect of lifting with team members of unmatched height. With the load variable, Dennis and Barrett (2003) examined the relationship between load mass distribution and spinal load during team lifting tasks. But to our knowledge no study has been conducted to study the effects of carrying methods and box handles on the team carrying. It is likely that the maximum acceptable weights selected by individuals in carrying team are significantly affected by the carrying methods and use of box handles. Therefore, the purpose of this study was to examine the effects of carrying methods and box handles on the team carrying capacity and efficiency.

2. Method

2.1. Subjects

Sixteen reimbursed female university students (age 19.6 ± 1.71 years, stature 158.9 ± 5.1 cm, weight 56.6 ± 9.4 kg) were recruited and divided into 8 groups according to their stature. The stature difference in each group was within 5 cm to minimize the effect on team carrying (Lee and Lee, 2001). Subjects kept the same partner during the experiment. There was a presentation introducing the experimental purpose and procedure to the subjects before the experiment. Moreover, subjects were asked to sign an agreement for participation in this research after it was ensured that they had no musculoskeletal injuries or cardiovascular disease.

2.2. Experimental design

This research used a randomized complete block factorial design, with blocking on each group, to examine the effects of different carrying methods and box handles for an 8-h work shift. The independent variables were lifting methods (parallel and tandem) and box handles (with and without handles). To examine the test–retest reliability of psychophysical approach, the subjects performed each combination twice in a random order. The dependent variables were psychophysically determined maximum acceptable carrying weight (MAWC), heart rates (HR) and ratings of perceived exertion (RPE). For comparison purposes, each subject performed one-person carrying tasks with and without handles in a random order. On any given day, data for only one experimental treatment was collected for each group. As a result, a total of 64 two-person team carryings (8 groups × 2 methods × 2 handles × 2 repeats) were performed. The size of the wooden boxes adopted in these experiments differed between one-person carrying and two-person carrying. The wooden box with handles for the individuals was 38 cm in length, 20 cm in width and 30 cm in height with two cutout handles of 10.5 cm × 4.5 cm located 4 cm under the edge and 10 cm away from the side. The two-person carrying box with handles was 38 cm long, 70 cm wide and 30 cm high with four cutout handles of 10.5 cm × 4.5 cm located 4 cm under the edge of the box and 10 cm away from the side on the sagittal plane. For the convenience of lifting box without handles, there were two 6 cm height boards built at the bottom of the box 10 cm from both edges for each box. The subjects' heart rates were monitored using a Heart Rate Monitor (Exersentry Model TM 3A).

2.3. Experimental procedures

A psychophysical approach (Snook, 1978) was used for each subject to determine her maximum acceptable weights for each experimental treatment performed. The subjects were allotted four 1-h training sessions to practice one-person and two-person carrying tasks until they were familiar with the experimental procedure. After the four training sessions, the subjects formally participated in the team carrying experiment. Before the test, each subject was required to read the psychophysical instructions, similar to those used by Snook and Irvine (1967), and then perform a 10-min warm-up exercise.

When the test began, the subjects were asked to adjust the weight of the box by adding or subtracting lead shots to the maximum they could carry in box comfortably at knuckle height between benches that were 3.6 m apart. The 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 (Snook, 1985).

The subjects were encouraged to make weight adjustments. They were also allowed to discuss with each other what was the maximum load that they might be able to carry during the two-person carry. To minimize emotional influence, no incentives or emotional appeals were applied. The entire adjustment process took about 20 min for each task. Once the weight was decided, the subjects were asked to continue carrying for another 10 min. The subjects' heart rate was recorded every 30 s during the last 10 min and the mean values over 10 min were used for analysis. At the end of each team carrying task, the subjects were asked to rate the perceived exertion (RPE) of the wrist, arms, shoulders, legs, lower back and whole body (Borg, 1985).

2.4. Experimental task

Subjects carried the box in front of them while performing one-person carrying. Two-person carrying was performed in parallel and in tandem. To prevent variation due to different hand positions while lifting, the hand placements for both one-person carrying and two-person carrying conditions were controlled. While performing parallel two-person carrying, the two subjects faced each other with two hands holding the cutout handles on the two sides or the bottom of the box, as shown in Fig. 1. The subjects followed one another while walking forward when performing the tandem two-person carry with two hands holding handles on the sides or the bottom of the box, as shown in Fig. 2. The experimental task for each trial included lifting the box from the floor, adjusting the weight of the box, carrying the box through the given distance (3.6 m), and placing the box on the floor. The carrying task was performed at a frequency of 1 min^{-1}. The average temperature of the laboratory was maintained between 22 °C and 24 °C and the relative humidity between 55% and 75%.

2.5. Statistical analysis

The dependent variables were the MAWC, HR and RPE. The independent variables were the carrying methods and box handles. The individual MAWC, HR and RPE were the means of both trials for each subject. To identify significant differences among the dependent variables, analysis of variance (ANOVA) statistical analysis procedures were employed. When variables were identified as statistically significant, Duncan's multiple range test was used for post hoc comparison to determine the source of the statistically significant effect. Cronbach's alpha statistic was used to examine test–retest reliability. An alpha level of 0.05 was selected as the minimum level of significance.

3. Results

3.1. One-person carrying capacity

Table 1 summarizes means (standard deviations) and ANOVA results of MAWCs, heart rates and RPE values for one-person carrying.