Hand Placement and Risk Assessment by the LMM Model

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Previous studies have shown a variety of hand placement locations employed by workers performing manual lifting tasks in industry. In this study, participants used four different hand placement locations to lift a box of variable weight and starting height. As they performed these lifts, the motions of their torso were captured using the lumbar motion monitor and these trunk kinematics were then input into the LMM low back injury risk assessment model. The results showed significant effects of all three independent variables with asymmetric hand placement locations generating the highest level of risk: 20% in the symmetric, 5kg condition as compared to a high of nearly 40% under the asymmetric, 10kg condition. These results indicate that hand placement is a relevant variable to consider when designing manual materials handling tasks.

INTRODUCTION

Hand placement during lifting has the potential to influence trunk postures and motions (and thereby low back injury risk). In a 1982 study, Drury and colleagues observed the self-selected hand positions as industrial workers performed lifting tasks. While a variety of hand positions were noted, they found that a diagonal strategy (one hand gripping upper front corner of box, while other hand gripped lower rear corner) was employed very often. This asymmetry of hand positioning has the potential to alter trunk postures and kinematics (transverse and coronal plane) and these have been shown to be risk factors for the development of low back injuries as assessed by the LMM risk assessment model (Marras et al., 1993). In another study, Drury and Pizatella (1983) found that hand positioning is very much influenced by many task variables (e.g. load mass, load location). The objectives of this study are to quantify the effects of hand placement on risk as assessed by the LMM risk assessment model.

METHODS

Participants

Fourteen participants (seven men and seven women) were recruited from the graduate and undergraduate student population to participate in this study. Subjects had an average age of 24 years, stature of 173 cm and whole body mass 70 kg. Each signed a written informed consent form and reported having no current or chronic lower back.

Apparatus

Trunk kinematic data were collected using the Lumbar Motion Monitor (LMM) (Chattanooga Group Inc., TN) (Marras et al. 1992) and these data were collected at a rate of 60 Hz.

The object lifted in this study was a 50cm (width) x 40cm (depth) x 24cm (height) handle-less (requiring a compression style lift in all conditions) cardboard box which its total mass was either 5 or 10 kg. Wooden platforms were used to position (vertically) the cardboard box at the given heights (30, 60 and 90 cm) and the box was centered on the platform to eliminate the possibility of wrapping the fingers underneath the box.

Experimental Design

Independent variables. There were three independent variables: hand placement location (four levels), load mass (two levels) and load height (three levels). The four levels of hand placements were (A) hands on the sides of the box at the bottom, (B) hands on the sides of the box at the top, (C) left hand on left upper proximal corner and right hand on the right lower distal corner of the box, and (D) left hand on left lower proximal corner and right hand on the right upper distal corner of the box (Figure 1).

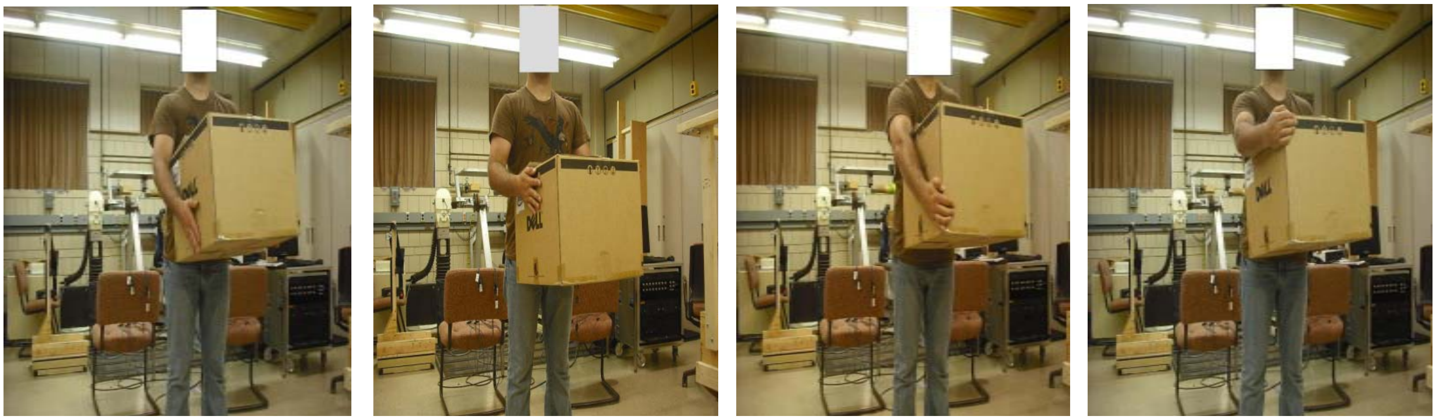

Figure 1: Hand placement locations. A: hands on the sides of the box at the bottom (unseen left hand is at bottom), (B) hands on the sides of the box at the top (unseen left hand is at top), (C) left hand on left upper proximal corner and right hand on the right lower distal corner of the box, and (D) left hand on left lower proximal corner and right hand on the right upper distal corner of the box.

Dependent variable. The dependent variable in this study was the Probability of High Risk Group Membership (PHRGM) as determined through the LMM low back injury risk assessment model (Marras et al., 1993) determined during the concentric lifting motion of each trial.

Experimental Task

After a short warm-up, the LMM was secured to the torso and the participant moved to the lifting area. Prior to conducting the experimental trials, a brief familiarization period was provided then participants were asked to align their feet on a piece of tape 38 cm from the center of mass of the box. This was done to standardize the moment of the load about the spine. Participants were instructed to use a stoop lifting technique with feet shoulder width apart because lower extremity positions may influence LMM output components. Subjects performed two lifts for each combination of independent variables and the order of presentation was completely randomized.

Data Analysis

The concentric phase began at the point of greatest sagittal flexion and ended when the participant returned to their upright posture. The peak coronal velocity was the peak of the absolute values observed and the mean transverse angular velocity was defined as the average of the absolute values of the angular velocity in the transverse plane. Finally, the peak sagittal acceleration value was found during the initiation of the concentric lifting motion. For each trial for each subject these data were used to calculate the value of the PHRGM (using lift rate of 2 lifts/min and sagittal moment of either 27Nm (for 5kg) or 54Nm (for 10kg).

Statistical analyses in this study were conducted using SAS®. Prior to conducting the formal statistical analysis, diagnostic tests were performed on the data. ANOVA was conducted to explore the effects of the independent variables.

RESULTS

The results of the ANOVA for the PHRGM variable provide some insight into the overall impact of these task variables on risk assessed by LMM model (Figure 2). All main effects and the interaction between hand placement location and load height were all significant ($p<0.05$). The smallest value of PHRGM was found for hand position B (with 5kg mass lifted at a height of 90cm) with an average value of just 20%, while the largest value was associated with hand position C (with 10kg lifted at a height of 30cm) at 38.1%. The value of PHRGM for hand position B was always smallest in comparison with other hand positions, which could be due to lower values for peak sagittal angle and having symmetric hand positions. Hand positions C and D consistently showed higher PHRGM values for equivalent levels of load height and load mass showing the effects of the asymmetry of the hand positions and thereby the trunk postures that resulted.

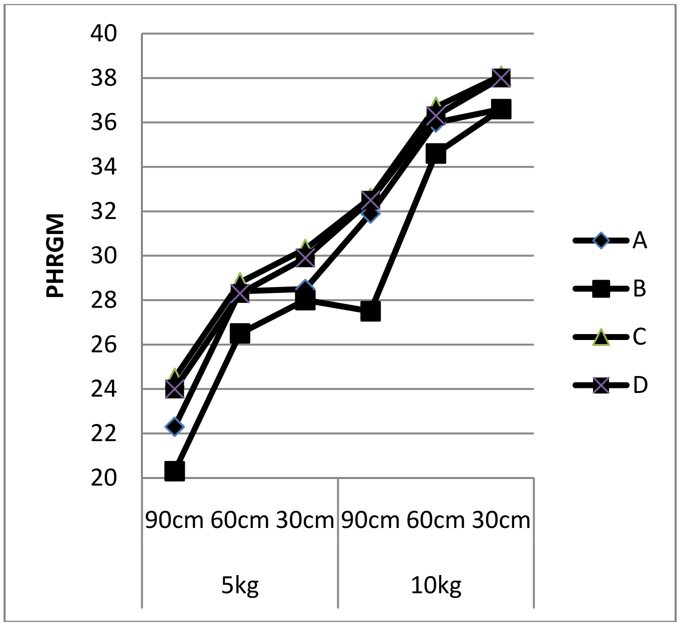

Figure 2: Interaction between hand placement location, load height, and load mass on PHRGM.

DISCUSSION

The hand positions used in this study account for roughly 64% of the hand positions observed in industry (Drury et al. 1982). The results of this study indicate that hand position does have a significant effect on the risk associated with a lifting task. Positions C and D are inherently asymmetric and will generate motions in the transverse and coronal planes thereby influencing the magnitude of the PHRGM measure. Our results (Figure 2) showed that shows that all PHRGM values increased with decreasing load height and load mass as a consequence of increasing the value of the peak sagittal angle PSA and moment. These results also indicate a significant interaction between hand placement location and load height for this variable, indicating a complex human performance aspect to this activity that should be considered in future research.

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