Psychophysiologically determining the maximum acceptable weight of lift for polypropylene laminated bags

Yi-Lang CHEN1, 2* and Ting-Kuang HO1

1Department of Industrial Engineering and Management, Ming Chi University of Technology, Taiwan
2Department of Industrial Design, Chang Gung University, Taiwan

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Abstract: The objective of this study was to psychophysically determine the maximum acceptable weight of lift (MAWL) for polypropylene (PP) laminated bags. Twelve men were requested to decide their MAWLs under various task combinations involving 3 lifting ranges, 3 lifting frequencies, and 2 hand conditions. The results revealed that the MAWL was significantly affected by the frequency and range variables (all \( p < .001 \)), whereas the hand condition did not influence the MAWL. The participants exhibited relatively low MAWL values compared with subjects in previous studies, especially in infrequent lifts. The results of multiple stepwise regression revealed that certain anthropometric data (e.g., chest circumference, wrist circumference, and acromial height) accounted for the percentage of variance for the determined MAWLs, ranging from 56.2% to 83.4%. These data can be obtained simply and quickly, and are considered the superior predictors for MAWL determination when handling PP laminated bags.

Key words: Psychophysics, Maximum acceptable weight of lift, Handles, Prediction model, Anthropometry

Introduction

The maximum acceptable weight of lift (MAWL) is one of the most widely used approaches for representing a person’s lifting capacity and is thus employed to design appropriate jobs1). When lifting, the weight and its distribution, shape, stiffness, and handles are object characteristics that must be considered in the design of lifting tasks2, 3). Previous studies found that good handles were theorized to reduce lifting stress, whereas poor handles were theorized to increase lifting stress4). Ciriello et al. reported that the maximum acceptable weight was approximately 16% lower when no handles were used and suggested that the load recommendations for the MAWL based on boxes with handles must be adjusted when applied to boxes without handles or other types of containers5).

However, numerous MAWL studies have focused only on rigid boxes with well-designed handles. In practice, many manual material handling tasks exist in manufacturing and service industries, logistics, and agriculture that require people to lift soft bags without handles, such as polypropylene (PP) laminated bags, for transporting goods; loading and unloading bags, boxes, or cartons; removing materials from a conveyor belt; and stacking goods in a warehouse6). Therefore, the aim of this study was to psychophysiologically determine the MAWL for PP laminated bags and to develop candidate predictors for the MAWL.

Methods

We recruited 12 male university students to participate in this study. Their mean age, height, and body mass were

*To whom correspondence should be addressed.
E-mail: ylchen@mail.mcut.edu.tw
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Table 1. Basic data of the twelve Taiwanese male participants in this study

<table>
<thead>
<tr>
<th>Items</th>
<th>Mean</th>
<th>S.D.</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>23.3</td>
<td>0.8</td>
<td>22.0 – 24.2</td>
</tr>
<tr>
<td>Stature (cm)</td>
<td>172.3</td>
<td>3.9</td>
<td>163.0 – 178.0</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>68.4</td>
<td>5.2</td>
<td>59.2 – 81.6</td>
</tr>
<tr>
<td>Acromial height (cm)</td>
<td>142.3</td>
<td>6.0</td>
<td>132.1 – 148.0</td>
</tr>
<tr>
<td>Knuckle height (cm)</td>
<td>75.8</td>
<td>2.9</td>
<td>68.3 – 81.8</td>
</tr>
<tr>
<td>Knee height (cm)</td>
<td>51.0</td>
<td>1.9</td>
<td>48.5 – 55.0</td>
</tr>
<tr>
<td>Chest circumference (cm)</td>
<td>19.0</td>
<td>1.5</td>
<td>17.5 – 22.8</td>
</tr>
<tr>
<td>Wrist circumference (cm)</td>
<td>16.1</td>
<td>0.8</td>
<td>15.0 – 17.5</td>
</tr>
<tr>
<td>Isometric strengths (kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composite strength</td>
<td>100.9</td>
<td>6.9</td>
<td>90.9 – 111.2</td>
</tr>
<tr>
<td>Back strength</td>
<td>56.3</td>
<td>14.0</td>
<td>32.3 – 77.2</td>
</tr>
<tr>
<td>Shoulder strength</td>
<td>34.9</td>
<td>5.5</td>
<td>28.8 – 50.5</td>
</tr>
<tr>
<td>Arm strength</td>
<td>30.9</td>
<td>4.1</td>
<td>23.0 – 35.8</td>
</tr>
</tbody>
</table>

23.5 years, 172.3 cm, and 68.4 kg, respectively. Table 1 shows the details. All participants reported being moderately physically active (leisure exercise at least twice a week), healthy and asymptomatic of illness and having no pre-existing injuries. Anthropometric measurements and standard isometric strengths were obtained by following the procedure detailed by Ayoub et al.\(^7\), which was applied for all participants for further regression analysis. The subjects participated voluntarily and underwent a physical examination conducted by a physician. Informed consent was obtained from all participants, and the Ethics Committee of Chang Gung Memorial Hospital approved this study.

Each participant determined his MAWL by using the psychophysical approach\(^8\), for each task condition. The assumption of psychophysical stress as an integration of psychophysical approach \(^8\), for each task condition. The subjects participated voluntarily and underwent a physical examination conducted by a physician. Informed consent was obtained from all participants, and the Ethics Committee of Chang Gung Memorial Hospital approved this study.

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Results and Discussion

The ANOVA results showed that the MAWL data were significantly affected by the lifting range \(F(2,198)=87.7, p<0.001, \eta^2=0.470\) and frequency \(F(2,198)=375.7, p<0.001, \eta^2=0.791\) variables. This result was in agreement with those reported by Lee et al.\(^8\) and Pinder and Boocock\(^9\). The MAWL values did not differ between the hand contact conditions \(F(1,198)=0.201, p=0.668, \eta^2=0.001\). Moreover, the interactions were found to have a non-significant influence on determining the MAWL,
The means and standard deviations of the MAWL values for all task conditions, as well as the Duncan MRT result, are listed in Table 2. A comparison of the MAWL data against those presented by Lee et al. (2016) is also displayed in the table. Compared with the previous Taiwanese data, the MAWL values of infrequent FK and KS tasks in this study were 4.2 kg and 3.6 kg, respectively, lower than those reported by Lee et al. (2016). This may be attributed to the boxes used by Lee et al. having handles. Garg and Saxena (2010) indicated that the average MAWL for six boxes with different dimensions that were tested without handles was lower (ranging from 4.0% to 11.5%, with an average decrease of 7.2%) compared with that for boxes with handles. Ciriello et al. reported that the maximum acceptable weight was approximately 16% lower when no handles were used (2015). However, this was insufficient for gaining an understanding as to why the effect of the handles was not observed in the FS task (with a difference of 1 kg). Moreover, it seems that the handle effect existed only in the infrequent task (i.e., OTM in this study). Smith and Jiang (2011) reported that the MAWL for bag lifting was higher (2.2 kg) than for box lifting in FS tasks with a frequency of 6 lifts/min. Our results were consistent with theirs when performing the frequent tasks. The results implied that handle effect may interact with other task variables in lifting. Further comparative studies in the handle effect may be required to clarify these ambiguities.

Table 3 lists the R-squares of the significant factors for predicting the MAWL by using the participants’ anthropometric data and isometric strength values as inputted for all 9 task conditions. Because an effect of gloves on the MAWL was not found, the prediction models were developed without considering the glove condition. In this study, the body mass was added to the MAWL as a dependent variable to identify the significant predicting factors from previous studies (2016, 2012). Anthropometric data (cumulative R² ranged from 0.562 to 0.834) were considered to have superior predicting power compared with those reported in previous studies (2016, 2012) in which boxes were equipped with well-designed handles. However, all strength values were not selected as the significant predictors. Among these significant factors, the chest circumference (CC) was the most preferentially selected predictor for all 9 lifting tasks, with the accounted variance ranging from 43.5% for the FSM task to 67.8% for the FK1 task. This result is in agreement with that reported by Lee and Chen (2012). The wrist circumference (WC) was also a significant factor for MAWL prediction in this study. To the best of our knowledge concerning related past studies, the WC has seldom been selected as a factor in a MAWL prediction model for boxes with handles. In addition to the CC, a generally accepted significant predictor, the WC may be another critical index for predicting MAWL in cases without handles (e.g., PP laminated bags). Furthermore, the acromial height (AH) was determined to be a suitable predictor for KS tasks, as shown in Table 3. This result is...
in agreement with the regression model developed by Lee and Chen\(^{12}\).

**Conclusions**

Twelve Taiwanese male students were recruited to determine their MAWL values when lifting PP laminated bag under various task combinations. Results also showed that the CC, WC, and AH accounted for 56.2% to 83.4% of the MAWL variations. These candidate factors are presented for use in predicting the lifting capacities for various lifting ranges and frequencies. Therefore, tasks can be pre-screened and assigned to specific populations according to measured anthropometric data. The usefulness of the measure for providing the predictive factors for other populations (e.g., industrial workers, women, and older people) warrants further investigation.

**References**


