Ergonomic Optimization of the Handle Width and Alignment Angles for the Three- or Four-Wheel Barrows

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Abstract: This study aimed to optimize the three handle variables (handle width, vertical angle and horizontal angle) using the central composite design method. Twenty healthy female subjects participated in the experiment. In the experiment, the independent variables were handle width, horizontal angle, and vertical angle, and the pushing forces were collected using a force gauge. The central composite design was applied and a total 17 treatment conditions were tested. Using the average force data of the 17 treatment conditions, a second order response surface model was extracted. Using the second order response model, the optimal solution set for the handle width, horizontal angle, and vertical angle was determined. The objective function in this optimization process was to maximize the pushing force. The optimal solution set of handle width = 1.25*shoulder width, horizontal angle = -10°, and the vertical angle of -10° was found. It is expected that this condition can maximize the pushing force or minimize the musculoskeletal load when exerting a submaximal pushing force.

Key Words: Central Composite Design, Optimization of the Handle Variables, Three-wheel or Four-wheel Barrow, Response Surface Methodology

Introduction

Work-related musculoskeletal disorders (WMSDs) are a term used to refer the symptoms of discomfort, disability impairment, or persistent pain in joints, muscles, tendons and other soft tissues, which are caused or aggravated by work.1) Serious economical and social problems such as extensive medical expenses, wage compensation, and reduced productivity, as well as worker’s physical and psychological pain have been caused by WMSDs.2)

In Korea, the percentage of the WMSDs in the total compensation for the industrial disease showed continuously increasing pattern during recent 3 years (45.8% in 2010, 43.0% in 1009, and 33.9% in 2008).3-5) Also, the compensation cost for

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the WMSDs is showing a continuous increase, and the total cost of the WMSDs compensation in 2010 was more than 3,500,000,000,000 won. In the case of America, about two percent of the entire American workers suffer from WMSDs every year\(^6\), and this is responsible for over 1/3 of all worker compensation costs.

Despite the mechanization and factory automation, manual materials handling tasks such as lifting, lowering, pushing, pulling and carrying are still prevalent in various industries including agriculture, manufacturing, and service industries.\(^7\) These MMH tasks have been known as potential risk factors to the WMSDs,\(^8\) and comprises a big portion in the total WMSDs.\(^9\)

To prevent WMSDs caused by MMH tasks, many powered or assistant tools for manual materials handling have been used. These cart, truck, barrows have been one of the major research topics in the ergonomics discipline in developed countries. Glitsch et al. investigated the physical workload of flight attendants when using trolleys aboard Aircraft,\(^10\) Das et al. (2002) studied hospital meal cart\(^11\). Also, Lin et al. in 2010 studied the force exertions and muscle activities when operating a manual guided vehicle\(^12\). The usage of these carrying tools could be efficient in the aspect of energy consumption,\(^13\) there have been some reports that the workers still had pains or got injuries from using the carrying tools.\(^13\) The major reason of the pain and injuries could be the misuse of the tools and the wrong design of the carrying tools that is unfit to the human workers.

To the knowledge of the author, there is no guidelines or standards according to the handle variables are critical values for the design and manufacturing the carrying tools, particularly barrows. Among many types of barrows, the three-wheel or four-wheel barrows require only pushing forces to maneuver, while the two-wheel barrow requires lifting and pushing forces, and the one-wheel barrow requires lifting, pushing, and rolling forces.

This study conducted to determine the handle variables (handle width, and inclination angles) for the three-or four-wheel barrows, particularly for the women workers.

**Methods**

**Subjects**

Twenty female subjects participated in the experiment. They have no previous and present WMSDs symptoms and are all healthy. Their mean age was 39.1 ± 11.8 years, and mean height was 160.3 ± 4.2 cm. Including these information, relevant anthropometric measures (shoulder width, fist height, weight) are presented in Table 1. The mean weight was 57.8 ± 7.3 kg, the mean shoulder width was 37.1 ± 2.1 cm, and the fist height was 75.0 ± 2.8 cm.

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean</th>
<th>S.D.</th>
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<tbody>
<tr>
<td>Age (years)</td>
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<td>11.8</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>160.3</td>
<td>4.2</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>57.8</td>
<td>7.3</td>
</tr>
<tr>
<td>Shoulder Width (cm)</td>
<td>37.1</td>
<td>2.1</td>
</tr>
<tr>
<td>Fist Height (cm)</td>
<td>75.0</td>
<td>2.8</td>
</tr>
</tbody>
</table>

**Apparatus**

To measure the pushign forces with various