Workload Analysis by Using Nordic Body Map, Borg RPE and NIOSH Manual Lifting Equation Analyses: a Case Study in Sheet Metal Industry

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Abstract. The purposes of this research were to identify the lifting complaints experienced by the painting operators in the sheet metal industry at west java, Indonesia. The lifting issues such as operators’ lifting effort and risk were evaluated by combining the Nordic Body Map, the Borg Rating of Perceived Exertion and the NIOSH manual lifting equation tool. Specifically, two questionnaires that consist of Nordic Body Map and Borg Rating of Perceived Exertion and field observation were used as the research methodologies to evaluate respondents’ lifting process when loading the panel box, where its body part, door part and base plate were examined. All of the 44 full-time operators in the painting department of the sheet metal company participated in this study. Their age ranged from 20 to 40 years old. Five complaints were identified by Nordic Body Map questionnaire. These complaints were pain, discomfort, and tingling at operators’ neck, shoulders, and hips. Finding from Borg Rating of Perceived Exertion questionnaire revealed that the effort needed to lift the panel body parts were substantially higher than door parts and base plate. A new manual conveyor was then installed and the study’s recommendations were proven to be successful by reducing the 1991 NIOSH lifting index value from 1.65 to 0.91 when lifting panel body part, from 1.3 to 0.72 when lifting panel door part, and from 0.93 to 0.51 when lifting panel base plate. The value of the Borg Rating was also decreased from 13.79 to 11.96 for panel body part, from 9.36 to 8.82 for panel door part, and from 8.82 to 8.25 for panel base plate, and the lifting complaints of the painting operators were reduced.

Keywords: Lifting, Nordic Body Map, BORG Rating of Perceived Exertion, NIOSH manual lifting equation.
1. Introduction

Indonesia, as one of the developing countries, requires a sufficient supply of electricity to be distributed to the manufacturing factories. In line with this, of course, it takes an enormous amount of electrical panels containing electrical components. The electrical panels are made of sheet metal material. There are several steps to be able to make the electrical panel. First, sheet metal is cut by means of punching and bending in order to get the box form. Once bent, then every corner of the parts connected by means of welding. Painting is the next step, where the system of painting is done using powder coating. After all parts painted finish, the final step is to assemble the panel. In the painting process, there are several steps that must be done, ie the process of pre-treatment, drying 1, powder coating process, ends with the drying 2 process.

The placement and position of the panel’s parts are very essential, especially when the operators need to move them from one station to the other station. Operators need to maintain their body posture in order to lift the panel’s parts. NIOSH Recommended Weight Limit (RWL) equation and Lifting Index (LI) are based on the concept that the risk of lifting related low back pain increases as the demands of the lifting task increase [1]. The equation is widely accepted and used throughout industry in setting acceptable lift limits for workers.

Manual handling and lifting are a major cause of work-related Low Back Pain (LBP) and impairment [2]. LBP also can occur by direct trauma, a single exertion or potentially as the result of multiple exertions ("repetitive trauma") [3]. Painting operators must lift parts from the first drying oven (static oven) to the powder coating process. Based on these observations, this study aimed to analyze the complaints experienced by the operators in the department of painting and the risk of their body. Hopefully this research can provide inputs for companies engaged in sheet metal fabrication to improve the efficiency of the operator.

More than thirty years ago, the National Institute for Occupational Safety and Health (NIOSH) recognized the growing problem of work related back injuries and published the Work Practices Guide (WPG) for Manual Lifting [4]. The NIOSH WPG (1981) contained a summary of the lifting-related literature before 1981; analytical procedures and a lifting equation for calculating a recommended weight for specified two-handed, symmetrical lifting tasks; and an approach for controlling the hazards of low back injury from manual handling [1].

On 1991, the revised lifting equation reflects new findings and delivers methods for evaluating asymmetrical lifting tasks, and lifts of objects with less than optimal couplings between the object and the workers’ hands. The revised lifting equation also provides guidelines for a more diverse range of lifting tasks than the other equation [2].

About 1993, Waters et al suggest a new revised lifting equation [2]. The recommended weight limits derived from the revised equation are consistent with, or lower than the generally reported in the letter. Moreover, the proper application of the revised equation is more likely to protect healthy workers for a wider variety of lifting tasks than methods that relies only a single task factor or single criterion [13].

The concept of perceived exertion was introduced half a century ago and an operational definition presented with methods to measure different aspects of perceived effort, strain and fatigue [4]. One very common method is the RPE-Scale for "Ratings of Perceived Exertion" ("the Borg Scale") officially now: the "Borg RPE Scale".

2. Methodology

The aims of this study are to identify the complaints experienced by the operator using a Nordic Body Map questionnaire, to analyze how big the effort needed by using the BORG Rating Perceived Exertion, to analyze the risk incurred by using the NIOSH lifting equation, to propose an improvement plan for the department of painting by design tools [5, 6].

The study was conducted in the painting department from Contract Manufacturing, Sheet Metal Business Unit – Indonesia. The data needed for this research are the layout of the manufacturing plant,
work process detail, effort of the operators, vertical distance, horizontal distance, subjective perception of the operator and time study for the lifting process [7].

Figure 1. Operator Body Posture

3. Analysis and Result
There are 51 workers in the painting department, consist of 1 supervisor, 2 leaders, 8 coordinators, 32 powder coating operators, 4 treatment operators, and 4 HSE & Inventory operators. The Panel box divided into body, door, and base plate, with the size 600*400*180+20 mm. Figure 1 shows the body posture of the operator when lifting the body of the panel.

| Multiplier      | Formula                      | Parameter          | Value  |
|-----------------|------------------------------|--------------------|--------|
| Load Constant (LC) | 23 kg                        | 23 kg              | 23 kg  |
| Horizontal (HM)  | 25/H                         | H = 35 cm          | 0.714  |
| Vertical (VM)    | 1- (0.003 | V-75 | )          | V = 160 cm | 0.745 |
| Distance (DM)    | 0.82 + (4.5/D)               | D = 160 cm         | 0.850  |
| Asymmetry (AM)   | 1- (0.0032 x A)              | A = 30º            | 0.904  |
| Frequency (FM)   | Table Frequency multiplier    | 3 lifts/min        | 0.550  |
| Coupling (CM)    | Good, Fair, Bad              |                    | 0.270  |

Table 1. Summary For Recommended Weight Limit
From Table 1, the lifting frequency divide into two, the first one is to lift the body of panel which is 3 lifts/min, and the second is to lift the door and the base plate which is 6 lifts/min. From the calculation above, the Lifting Index for the three parts are more than 1.0. As we know, LI > 1.0 can increase the risk for low back pain or some fraction [8].

Table 2. Descriptive statistics BORG RPE Scale rated by 44 operators.

| Parts       | BORG RPE SCALE |
|-------------|----------------|
|              | Trial 1 | Trial 2 |
|              | Mean    | Std. Dev | Mean    | Std. Dev |
| Body        | 13.71   | 0.91     | 13.86   | 1.03     |
| Door        | 9.43    | 0.76     | 9.29    | 0.83     |
| Base plate  | 8.86    | 0.66     | 8.79    | 0.70     |

Table 3. Descriptive statistics lifting time

| Parts       | Lifting Time |
|-------------|--------------|
|              | Trial 1 | Trial 2 |
|              | Mean    | Std. Dev | Mean    | Std. Dev |
| Body        | 20.05   | 1.29     | 20.03   | 1.08     |
| Door        | 10.97   | 1.13     | 11.01   | 0.96     |
| Base plate  | 12.04   | 1.03     | 12.02   | 1.31     |

To examine the relationship between the Borg RPE scale and lifting time, then the correlation test using SPSS 18.0 was done. The result was there is a correlation between RPE Scale and lifting time for the first trial (0.992) and the second trial (0.996), as seen in table 2 and table 3. To obtain the subjective perception of complaints on certain body parts, the Nordic body map questionnaires were distributed to 44 operators. Questionnaires conducted over 26 working days. Figure 2 describes the percentage of complaints for 44 operators for almost 1 month. The operator was given an understanding of the Borg scale, the scale at which the operator provides a great perception of energy spent on lifting, ranging from no exertion at all to the biggest power is needed. This study was done twice and performed the time measurement when the operators lifted the panel, so the research is closer to the actual results [9-12].

From the Figure below, Upper neck, Waist and Back are the three biggest complaints among the other body parts. From the calculation of lifting index, the value of LI for the three parts is bigger than 1.0, which can increase the low back pain risk. From the Nordic Body Map Questionnaire, the biggest complaints rated by operators are upper neck, waist, and back. the conveyor table was made by using anthropometry data from West Java – Indonesia’s workers as an improvement tool. The anthropometry data used are standing waist height and hands reaching. After the painting pre treatment process, panel parts (Body, door and base plate) will glide through the pipes of the conveyor. Based on this improvement tool, recalculate the RWL & LI must be done. Here is the summary of the calculation: The RWL is 8.37 kg for 3 lifts/min and 4.1 kg for 6 lifts/min. When the operators use the improvement tool, a lowering value of Lifting Index.
4. Conclusion
Based on the results of Nordic Body Map Questionnaire, for the one month, the operators have complaints such as pain, discomfort, and tingling in the neck, back and waist. The Borg RPE scale is used to assess how big the effort to lift the parts. From Borg Rating of Perceived Exertion questionnaire revealed that the effort needed to lift the panel body parts were substantially higher than door parts and base plate. From NIOSH manual lifting equation measurement found that the biggest risk of injury was the operators’ lower back. Complaints submitted by the operator that pain in the waist, back and neck was indeed a great risk in line with the work. Using anthropometric dimensions of workers in West Java, the authors proposed an improvement tools such as conveyor table. Basic selection conveyor table this is a fairly low cost factor, and a fairly short time of manufacture. After testing by using a conveyor table, it is evident that these tools help to reduce the workload of the operator. as shows in table 4, calculation results lifting index value were reduced by 44-45%. While the Borg scale was also reduced to 6-15%, as seen in table 5. Proved by the existence of these tools, operator workload can be reduced. Design and manufacture of improvement tool can be proceeded with the manufacture of conveyor table that can adjust height, and the addition of wheels on the legs so that the conveyor table can serve as a lorry.
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