Study of Maximum Acceptable Weight of Lift for Indian Male Industrial Workers

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Abstract

Most of studies on Manual Material Handling (MMH) tasks for finding lifting capacity were done on general population; these were not done for underweight, normal weight and overweight workers. MMH task involves the use of the human body to lift, lower or carry loads. The purpose of this study is to evaluate the effect of psychophysical approach on MAWL for underweight, normal weight and overweight male workers with participants lifting weights at different Heights & lifting frequencies. Three male Indian workers with different body mass index (BMI) were participated in this study using general factorial design to find out MAWL of different lifting task combinations by performing free style lifting technique.

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1. Introduction

Most manufacturing, industrial or distribution systems require some manual material handling (MMH) tasks. When performed incorrectly or excessively, these tasks may expose workers to physical risk factors, fatigue, and injury. Manual materials handling is among the most frequent and most severe causes of musculoskeletal disorders all over the world [1]. These musculoskeletal disorders not only have a bad effect on worker's health but it also reduces the productivity of workers. Musculoskeletal disorders due to MMH tasks can be prevented by proper designing of MMH tasks by taking maximum load to be lifted less than the manual load lifting capacity under similar circumstance. The psychophysical approach has been widely utilized to determine the MMH task capability. The psychophysical approach proposed by Snook &Irvine [2] has been extensively utilized to investigate human capacity in manual material handling tasks. Maximum acceptable weight of lift (MAWL) is the highest acceptable weight, which can be lifted comfortably. Snook [3] method of calculating MAWL is the most popular way of calculating an individual's handling capability. A subject selects a weight randomly, and adjusts it to the maximum that a person can lift without feeling strain or discomfort, or becoming tired, weakened, overheated, or out-of-breath. Ciriello & Snook studied the effect of size, distance, height and frequency effects on manual materials handling tasks [4]. Wn studied the effect of MAWL for experienced Chinese male workers and found that the MAWL decreased significantly with the box size and lifting frequency, while the mean heart rate increased markedly with the box size and lifting frequency [5]. Wu & Chen showed that the maximum acceptable weights were affected significantly by the adjustment period [6]. The MAWL decreased with an increase in the adjustment time. However, the physiological costs demonstrated no significant difference among the four adjustment Periods. In addition, the effect of the adjustment period on the rating of perceived exertion was significant. In another study by Ciriello it was found that the maximum acceptable weights were affected significantly by the adjustment period [7]. Cheng & Lee studied the maximum acceptable weight of carriage (MAWC) for young Taiwanese males experienced in manual load carriage tasks and found that MAWC decreases with carriage distance, frequency and box width [8]. Maiti & Ray found that the increase in vertical lifting distance caused a significant decrease in load weight for Indian female workers [9]. The purpose of this study is to evaluate the effect of psychophysical approach on MAWL of Indian male workers. So based on the Industrial survey of MMH tasks in North Indian (Punjab) industries various MMH tasks parameters were selected and analyzed in laboratory with different combinations of Box size, Body Mass Index (BMI), Frequency of lift and Vertical distance of lift. MAWL was the psychophysical response factors selected for this study. Analysis of variance (ANOVA) was used for the statistical analysis of the experimental results.

2. WORKERS PARTICULARS

An anthropometric kit was used to measure anthropometrical data. Body weight was measured without shoes using a portable digital scale. The Body Mass Index (BMI) was calculated by dividing body mass of a person (in kilogram) by square of his height (in meter). BMI is used to indicate if an individual is underweight, normal or overweight. WHO categorized persons in three types namely underweight, normal weight and overweight based on their BMI [10]. A normal weight person BMI score is between 18 and 25 kg/m^2. A score below 18 indicates that a person is underweight; a value above 25 indicates that a person is overweight. . Three male industrial workers with different BMI and having 10 years of industrial experience were selected for this laboratory study. Worker with different BMI were selected because same work is done by workers with different BMI in different industries. Their selections were based on criteria of not having any kind of back pain, body discomfort or any sort of disease. The workers were selected from similar age range and engaged in approximately same type of daily Manual load lifting work activities.

Table 1. Anthropometric details of the Workers

Parameter of workers	Under weight	Normal weight	Over weight	Mean
Age (years)	33	28	30	30.3
Weight (kg)	40.2	57.4	61.9	53.2
Height (cm)	158.6	165.3	153.2	159.0
BMI Kg/m^2	16.1	21.08	25.93	21.0
Knee height (cm)	45.2	48.1	43.8	45.7
Crotch height (cm)	64.1	68.4	63.5	65.3
Waist height (cm)	96.7	102.3	92.2	97.1
Chest height (cm)	113.5	122.2	111.9	115.9
Axial height (cm)	125.3	129.4	117.6	124.1
Shoulder height (cm)	129.1	133.8	127.5	130.1
Chest breadth (cm)	29.3	31.4	33.8	31.5
Waist breadth (cm)	27.2	29.2	34.5	30.3
Hip breadth (cm)	28.5	31.2	31.4	30.4
Upper arm length (cm)	26.3	28.5	26.2	27.0
Forearm length (cm)	27.1	27.4	24.9	26.5

2.1. Measuring equipment details

A height adjustable set up was used to vary the lifting heights for lifting the weighted box. Stop watch was used for time measurement and instructing the subjects. Digital weighing equipment was used for measuring and adjusting weights.

3. EXPERIMENTAL DESIGN

The experiments were designed to study the effect of independent factors at different levels on response variables, as shown in table 2. Generalized full factorial design was used. The independent variables were: box size (Large and Small), BMI (Under, normal and overweight worker), frequency of lift (two, four and six lifts per minute) and vertical distance of lift (knee, waist and Shoulder height). Thus, there were fifty four lifting sequences (Two lifting boxes x Three different BMI Worker x Three lifting heights x Three lifting frequencies) for each subject. Each experiment was repeated three times. Free style lifting technique was used for all experiments.

Table 2. MMH task Parameters at Different Levels

S.No	Symbol	Factors	Levels			Units
			Level-1	Level-2	Level-3	
1	A	Box size	Small	Large	-------	cm^3
2	B	BMI	Under weight	Normal weight	Over weight	kg/m^2
3	C	Freq. of lift	2	4	6	lifts/min
4	D	Vertical distance	Knee	Waist	Shoulder	cm
Horizontal distance: 25cm, Environment conditions : 32$\pm$2^{0}C						

The maximum acceptable weight of lift (MAWL) was the primary response variable. Two wooden boxes of sizes 6*4*1.75 and 6*4*2.25 m3 were used for the experiments. These boxes were rectangular in shape which is shown in figure 1.

Figure1. Various Boxes used in experiments

3.1. EXPEREMENTAL SETUP

The experiments were conducted in laboratory where room temperature was maintained at32$\pm$2^{0}C. A height adjustable set up was used to vary the lifting heights for lifting the weighted box. A psychophysical approach was used by the participants to determine the maximum acceptable weight of lift to them for each of the 54 different lifting tasks performed. A free-style lifting method was used and the MAWL was determined psychophysically. The pebbles were used as the load material for the experiments. Lifting of the boxes was done as per the experiment array by the worker on the experimental setup while lowering of the boxes was done by volunteers.

3.2. METHODOLOGY

A psychophysical approach used by Snook [3] to determine the maximum acceptable weight of lift of the workers for each of lifting tasks was used for all experiments. First the anthropometric dimensions of the workers were taken and then they were asked to perform lifting tasks. The instructions given to the participants were the same as those used by Snook & Irvine [2]. A base load of 18 kg was taken for all the experiments. The participants were asked to adjust the weight of the box by adding to maximum the amount that they could lift comfortably at a different lifting frequencies for duration of 8 h. The participants were instructed to lift as much load as they could without straining themselves, or without becoming unusually tired, weakened, overheated or out of breathe. Each participant was encouraged to make weight adjustments. The entire adjustment process took about 15-20min for each task [11]. Once the weight was decided upon, the subject was asked to continue to lift for another 10 min. The final weight was noted down. The above procedure is also shown by flowchart in Figure 2.

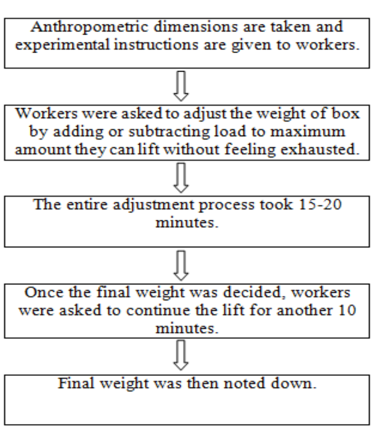

Figure2. Flowchart showing steps for calculating MAWL

4. RESULTS

Results obtained from the experiments were analyzed using the ANOVA, which helps in predicting the significance of independent factor for any desired response function. It indicates which is the most influencing factor or parameter. A confidence interval of 99% has been taken for this analysis. The principle behind significance value is that the p value should be lesser than 0.01 (considering confidence level of 99%) and lesser than 0.05 (considering confidence level of 95%). Significance of all the response variables has been completed using statistical software MINITAB. These response variables studied in this study was MAWL.

Table3. ANOVA results of various parameters for MAWL

Source	Sum of square	DF	Mean square	F value	Prob> F
Model	3234.44	53	61.03	116.74	< 0.0001
A	81.21	1	81.21	155.34	< 0.0001
B	255.98	2	127.99	244.83	< 0.0001
C	639.87	2	319.94	611.99	< 0.0001
D	2065.06	2	1032.53	1975.09	< 0.0001
AB	2.27	2	1.14	2.17	0.1187
AC	1.1	2	0.55	1.05	0.3527
AD	2.07	2	1.04	1.98	0.1424
BC	14.79	4	3.7	7.07	< 0.0001
BD	8.8	4	2.2	4.21	0.0033
CD	148.54	4	37.13	71.03	< 0.0001
ABC	0.31	4	0.076	0.15	0.9643
ABD	0.96	4	0.24	0.46	0.7645
ACD	3.28	4	0.82	1.57	0.1882
BCD	7.77	8	0.97	1.86	0.0742
ABCD	2.43	8	0.3	0.58	0.7909

In above Table 3 Model F-value of 104.77 implies the model is significant. There is only 0.01% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob> F" less than 0.0500 indicate model terms are significant. In this case the main factors box size (A), BMI (B), lifting frequency (C), lifting height (D) were significant. Some of the two-way interaction effects were found to be significant: BMI (B) x lifting frequency (C), BMI (B) x lifting height (D), lifting frequency (C) x lifting height (D) are significant model terms.

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5. DISCUSSIONS

Three male workers of different BMI (under, normal and overweight) participated in this study. The purpose of this study was to find out the MAWL for different BMI workers. The main effect of various lifting parameters for MAWL is shown in figures 3. The interactions effects of lifting parameters for MAWL is shown in figure 4.Underweight worker mean MAWL for different box sizes, lifting height and frequencies were less as compared to normal and overweight worker. With the large box size the mean MAWL decreases. With the increase in BMI the MAWL increases.

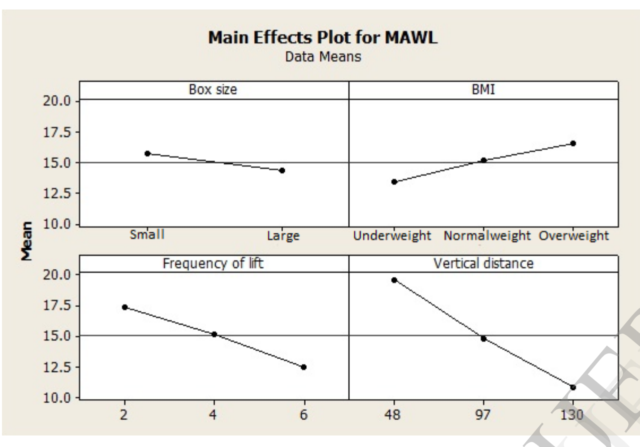

Figure3. Effect of main lifting parameters on MAWL

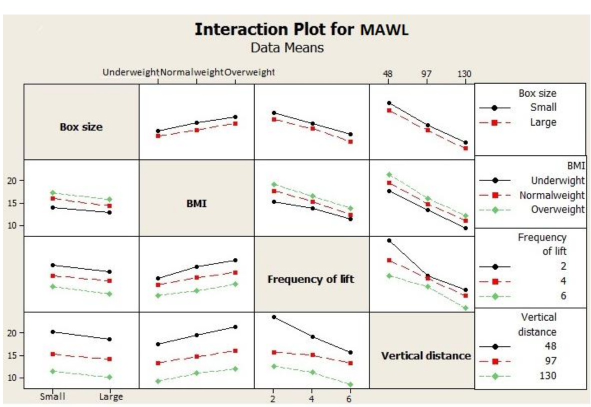

Figure4. Effect of interaction of lifting parameters on MAWL

Analysis of variance in Table 3 showed the maximum acceptable weight of lift was significantly influenced by box size ($p < 0.01$). The effects of box size on MAWL is shown in Figure 3. It was found that the maximum acceptable weight of lift decreased as box size increased. When the box size increased from, Box-1 (small) to Box-2 (large) the mean MAWL decreased, by approximately 8.9% from 15.72 kg to 14.32 kg. The reason behind is that with smaller box subjects preferred lifting more weight as compared to large box.). There was increase in MAWL with increase in BMI as shown in Figure 3. As the BMI increased from underweight to normal weight, the average MAWL increased by nearly 11.10% from approximately 13.45kg approximately 15.13 kg. A further increase of 8.41% from 15.13kg to 16.52 kg was observed when the BMI was increased from normal weight to overweight. Based upon the analysis of variance, the maximum acceptable weight of lift was significantly influenced by frequency ($p < 0.01$).There was decline in MAWL with frequency, shown in Figure 3. As the frequency increased from two lifts/min to four lift/min, mean MAWL declined by nearly 12.70% from approximately 17.39kg to 15.18kg. A further decline of 17.45% from 15.18kg to12.53kg was observed when the lifting frequency increased to six lifts/min. Analysis of variance in Table 3 showed the maximum acceptable weight of lift was significantly influenced by lifting height ($p < 0.01$). There was decline in MAWL with height as shown in Figure 3. As the height increased from Knee to Waist, the average MAWL decreased by nearly 24.51% from approximately 19.54kg approximately 14.75 kg. A further decrease of 26.71% from 14.75kg to 10.81 kg was observed when the lifting height increased to Maximum reach height.

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CONCLUSIONS

This study was conducted to evaluate the effect of box size, BMI, frequency of lift and vertical distance on the response variables on lifting capabilities of the Indian male workers, based on the psychophysical approach. The results show that the MAWL decreased significantly with the increase in Box size, lifting frequency and vertical distance and increase with increase in the BMI of the worker. It can be concluded from the study that MAWL is affected by lifting in Box size, BMI of the worker, lifting frequency and vertical distance.

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