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# Study the Effect of Box Grip and Back Belt on Manual Lifting Tasks for Indian Male Workers

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***Abstract: A laboratory experiment was conducted to determine the effects of Box grip, Back belt and other different parameters on Heart rate (HR). Three male experienced industrial workers recruited as participants. Each participant performed six different lifting tasks. Three lifting frequencies (3, 6, and 9), three vertical distances (i.e. knee, waist, shoulder) and three different loads (i.e. 7, 14, and 21) a horizontal distance of 25 cm and 10 min experimental time considered. The results showed that (1) The HR was significantly lower with Back belt and more without Back belt. (2) Box grip had also significant effect on the HR the value of HR was lower with Box with slotted grip and more with Box without handle grip. (3) In case of lifting frequency the value of HR is more with frequency 9 and less with frequency 3. Both the physiological costs (HR) increased with an increase in lifting frequency. (4) HR increased with vertical distance at shoulder and decreased with vertical distance at knee. (5) The value of HR is more with load of 21 kg and is less with load of 7 kg.It is generally believed that manual lifting without Back support is more harmful for our cardiovascular system. HR increases rapidly when manual lifting is done with Box without handle grip and without Back belt support. However, the previous studies were conducted in Europe and America, and the data were obtained from the different populations. This work, therefore, aims to investigate the influence of Back belt and Box grip on HR of industrial labour during manual lifting task.***

***Keywords:*** **Heart rate (HR), Back belt, Box grip.**

## I. INTRODUCTION

Manual materials handling (MMH) is a component of many jobs and activities undertaken in life. Typically it involves lifting, lowering, pushing, pulling and carrying objects by hand. Loading and unloading trucks, carts, boxes or crates; moving parts or assemblies from one place to another; loading paper to the copier or picking binders from an overhead shelf; lifting patients from a bed or transporting them in a wheelchair are typical MMH activities found in work settings. Likewise, carrying groceries to the kitchen or garbage cans to the curb, picking up sticks in the yard or mowing the lawn, or simply holding a child in your arms are forms of MMH we encounter at home. This is by no means an all-inclusive list of MMH tasks. Manual materials handling permeates all aspects of life on and off the job. Even with all the technology available today, manual materials handling will always be with us. The physiological approach is concerned with energy consumption and the stresses acting on the cardiovascular system. As we perform a repetitive lifting task, our oxygen consumption increases, our heart beats faster, and muscles become fatigued. This is the physiological cost associated with the activities we perform. While the biomechanical approach is most useful in analyzing infrequent lifting tasks, the physiological approach is most applicable to repetitive lifting tasks. In this kind of job, the individual's physiological response is the limiting factor with respect to the work. ***Druryj G., et al (1989)*** studied the physiological and psychophysical costs of symmetric and asymmetric manual materials handling; two tasks were performed by 30 Useful in analyzing infrequent lifting tasks, the physiological approach is most applicable to repetitive lifting tasks. In this kind of job, the individual's physiological response is the limiting factor with respect to the work. ***Druryj G., et al (1989)*** studied the physiological and psychophysical costs of symmetric and asymmetric manual materials handling; two tasks were performed by 30 industrial subjects. Increases in both the box size and lifting frequency induced a significant increase in heart rate. Both the physiological costs (Heart rate and Oxygen uptake) and rating of perceived exertion increased with an increase in lifting frequency **Wu Swei-Pi, (2000).** In addition, lifting from the floor and lowering on the floor condition resulted in the highest physiological responses including both $V0_2$ and heart rate **Li Way Kai, et al. (2007).** One of the most widely accepted approaches in designing MMH tasks is to design or modify a job so as not to exceed the capabilities of the materials handlers **S.H. Snook (1978).** Physiological measures are one of the scientific means to evaluate the physical burdens and capabilities of workers in MMH tasks under various job conditions. In the physiological approach, a job is usually divided into individual tasks, and the physiological cost of the job is assumed to be the sum of the energy expenditures of these individual tasks.

## II. METHODS

The study was conducted on two daily wage workers of age 21-25. The full procedure of the experiment was explained to the workers. It was confirmed that the workers are healthy and free from musculoskeletal disorders or cardiovascular problem.

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**Table 1 Data of workers**

| Classifications | Age | Vertical distance | Height |
|---|---|---|---|
| Range | 21-25 | 59-64 | 162-167 |
| Mean | 23 | 61.5 | 164.5 |

## III. EXPERIMENTAL APPARATUS

The oxygen and heart rate of the daily wage worker was measured by a machine Cosmod to check the work discomfort. The test was conducted for 10 minutes. Three different size boxes were made (description of the boxes are shown in the table 2) with two Back belt positions on them. First position is on the top (5cm away from) the top edge and second at the mid of the box. The boxes were made of 1cm thick wood board. While making the boxes Drury's guidelines were kept in mind. The sharp edges and corners were removed for the safety from the boxes.

**Table 2 Box's specifications**

| Box sixes | Box grip |
|---|---|
| 58*38*18 | Without grip |
| 58*38*18 | Slotted grip |
| 58*38*18 | Handle grip |

## IV. EXPERIMENTAL PROCEDURE

Two conditions are used i.e. one is with Back belt and the other is without back belt. Optimality of the Back belt was checked at three different time durations, three different vertical Heights, three different Loads and at three different Frequencies. The detail of the Box grip, Frequency, Vertical distances and Loads are given in the table 4. Taguchi's L18 technique was used to perform the experiments. 18 experiments were conducted with different combinations of above given parameters and variables. And the horizontal distance was fixed in all experiments as 25 cm and each experiment was conducted for the time of 10mins. As **Grandjean (1985)** and **Green et al. (1986)** stated that HR reflects an increase in both mental and physical workloads. **Dutta** & **Taboun (1989)** shown that oxygen consumption varies when Vertical distance Back varies. HR of workers was measured to check the effect of above parameters and variables on the workers. Then the workers were asked to lift the box and place it up given height defined by Taguchi L18 techniques. The experiments were conducted at room temperature. Each experiment was repeated for three times to check the accurate value. The rest of 45 min was given to worker after performing the experiment. No moral support was given to the worker during the experiments.

**Table 3 Parameters with Taguchi's L18**

| S. No. | A=Back belt | B=Box grip | C=Worker | D=Frequency | E=Vertical distance | F=Load |
|---|---|---|---|---|---|---|
| 1 | No belt | No grip | 1 | 3 | Knee | 7 |
| 2 | No belt | No grip | 2 | 6 | Waist | 14 |
| 3 | No belt | No grip | 3 | 9 | Shoulder | 21 |
| 4 | No belt | With handle grip | 1 | 3 | Waist | 14 |
| 5 | No belt | With handle grip | 2 | 6 | Shoulder | 21 |
| 6 | No belt | With handle grip | 3 | 9 | Knee | 7 |
| 7 | No belt | With slotted grip | 1 | 6 | Knee | 21 |
| 8 | No belt | With slotted grip | 2 | 9 | Waist | 7 |
| 9 | No belt | With slotted grip | 3 | 3 | Shoulder | 14 |
| 10 | Belt | No grip | 1 | 9 | Shoulder | 14 |
| 11 | Belt | No grip | 2 | 3 | Knee | 21 |
| 12 | Belt | No grip | 3 | 6 | Waist | 7 |
| 13 | Belt | With handle grip | 1 | 6 | Shoulder | 7 |
| 14 | Belt | With handle grip | 2 | 9 | Knee | 14 |
| 15 | Belt | With handle grip | 3 | 3 | Waist | 21 |
| 16 | Belt | With slotted grip | 1 | 9 | Waist | 21 |
| 17 | Belt | With slotted grip | 2 | 3 | Shoulder | 7 |
| 18 | Belt | With slotted grip | 3 | 6 | Knee | 14 |

## V. RESULTS AND DISCUSSION

Taguchi recommends the use of S/N ratio to measure the quality characteristics deviating from the desired values. The quality characteristic for HR it is taken as "lower-the better". The S/N ratio for the "lower-the-better" of response can be computed (Ross, 1988; Roy, 1990) as:

$$(S/N)_{LB} = -10 \log [1/R \sum_{j-1}^{R} (Y_j^2)]$$

Where, $Y_j$ (j= 1, 2, 3…….n) is the response value under the trail condition repeated R times.

Analysis of Variance (ANOVA) is performed to identify the process parameters that are statistically significant. With the S/N and ANOVA analyses, the

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optimal combination of the process parameters is predicted. The design parameters as well as their chosen

## VI. EFFECTS ON HEART RATE

The optimal combination levels of the lifting parameters correlated with the condition of Back belt, lower HR are determined by analyzing the S/N ratios and levels considered for Taguchi experiments are listed in Table.

raw data values. Table 5 shows the experimental conditions using Taguchi L18 orthogonal array and measured values of HR for three different trial runs along with corresponding S/N ratio.

**Table 5 Main effects of HR (S/N Ratio)**

| Level | Back belt | Box grip | Worker | Frequency | Vertical distance | Load |
|---|---|---|---|---|---|---|
| L1 | -40.6945 | -41.0953 | -40.5433 | -40.3224 | -40.3562 | -40.2888 |
| L2 | -40.9721 | -40.6664 | -41.1039 | -41.0051 | -40.7538 | -40.744 |
| L3 | -- | -40.7382 | -40.8528 | -41.1725 | -41.39 | -41.4672 |
| L2-L1 | -0.27759 | 0.428937 | -0.56066 | -0.68275 | -0.39755 | -0.45512 |
| L3-L2 | -- | -0.07183 | 0.251174 | -0.16734 | -0.63619 | -0.7232 |
| Difference | -0.27759 | -0.50076 | 0.811835 | 0.515403 | -0.23864 | -0.26808 |

L1, L2 and L3 represent levels 1, 2 and 3 respectively of parameters. L2-L1 is the average main effect when the corresponding parameter changes from level 1 to level 2. L3-L2 is the average main effect when the corresponding parameter changes from level 2 to level 3.

**Table 6 Main effects of HR (Raw data)**

| Level | Back belt | Box grip | Worker | Frequency | Vertical distance | Load |
|---|---|---|---|---|---|---|
| L1 | 109.196 | 114.206 | 107.028 | 104.094 | 104.411 | 103.567 |
| L2 | 111.941 | 108.522 | 113.772 | 112.528 | 109.417 | 109.317 |
| L3 | -- | 108.978 | 110.906 | 115.083 | 117.878 | 118.822 |
| L2-L1 | 2.744 | -5.683 | 6.744 | 8.433 | 5.006 | 5.750 |
| L3-L2 | -- | 0.456 | -2.867 | 2.556 | 8.461 | 9.506 |
| Difference | 2.744 | 6.139 | -9.611 | -5.878 | 3.456 | 3.756 |

L1, L2 and L3 represent levels 1, 2 and 3 respectively of parameters. L2-L1 is the average main effect when the corresponding parameter changes from level 1 to level 2. L3-L2 is the average main effect when the corresponding parameter changes from level 2 to level 3.

**Table 7 Pooled ANNOVA (S/N Ratio)**

| Source | SS | DOF | V | F-Ratio | SS | P% |
|---|---|---|---|---|---|---|
| Back belt | 0.34675 | 1 | 0.34675 | 5.6284 | 0.34675 | 2.33156 |
| Box grip | 0.63335 | 2 | 0.31667 | 5.14018 | 0.63335 | 4.17124 |
| Worker | 0.94643 | 2 | 0.47321 | 7.68107 | 0.946425 | 6.731179 |
| Frequency | 2.43359 | 2 | 1.21679 | 19.7507 | 2.43359 | 18.8913 |
| Vertical distance | 3.26281 | 2 | 1.6314 | 26.4806 | 3.26281 | 25.67167 |
| Load | 4.23723 | 2 | 2.11862 | 34.3888 | 4.237231 | 33.63926 |
| Error | 0.36965 | 6 | 0.06161 | -- | 0.369646 | 8.563753 |
| Total | 12.2298 | 17 | -- | -- | 3.783338 | 100 |

*Significant at 95% confidence level, $F_{Table}$ (Back belt);5.99, $F_{Table}$ (Others);5.14
SS: Sum of squares; DOF: Degree of Freedom; V: Variance; SS': Pure Sum of Squares

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**Table 8 Pooled ANNOVA (Raw data)**

| Source | SS | DOF | V | F-Ratio | SS | P% |
|---|---|---|---|---|---|---|
| Back belt | 101.682 | 1 | 101.682 | 18.4567* | 101.682 | 1.57663 |
| Box grip | 359.025 | 2 | 179.512 | 32.5841* | 359.025 | 5.70514 |
| Worker | 412.455 | 2 | 206.227 | 37.4333* | 412.4548 | 6.581058 |
| Frequency | 1190.45 | 2 | 595.223 | 108.042* | 1190.45 | 19.3353 |
| Vertical distance | 1667.98 | 2 | 833.991 | 151.382.* | 1667.983 | 27.1639 |
| Load | 2136.9 | 2 | 1068.45 | 193.939* | 2136.9 | 34.8512 |
| Error | 231.386 | 42 | 5.5092 | -- | 2311.82 | 38.5317 |
| Total | 6099.88 | 53 | -- | -- | 6099.88 | 100 |

*Significant at 95% confidence level, $F_{Table}$ (Back belt);5.99, $F_{Table}$ (Others);5.14, SS: Sum of squares; DOF: Degree of Freedom; V: Variance; SS': Pure Sum of Squares

The effect of process parameters on HR for both the raw data and S/N ratio are analysed using ANOVA. The optimum combination levels of process parameters are determined from the raw data and S/N ratio response graphs plotted in Figure 3 to 8.

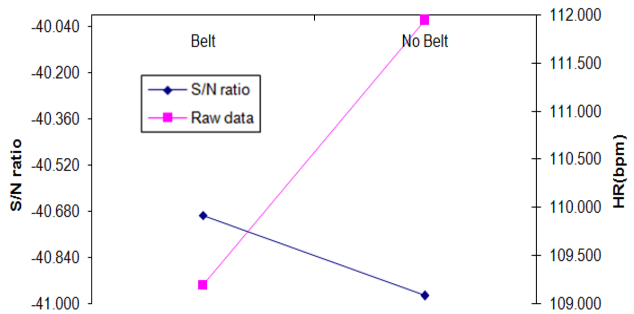


**Fig 3 shows the effect of belt on HR**

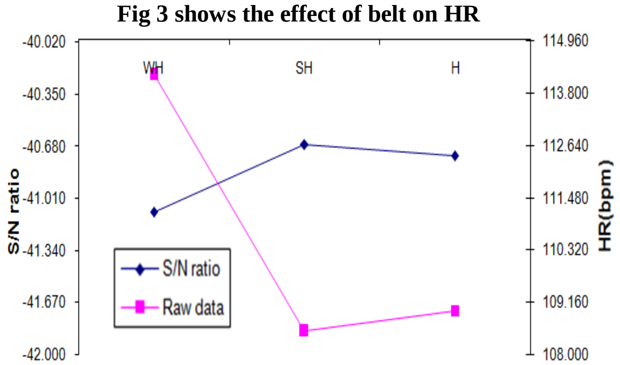


**Fig 4 shows the effect of box grip on HR**

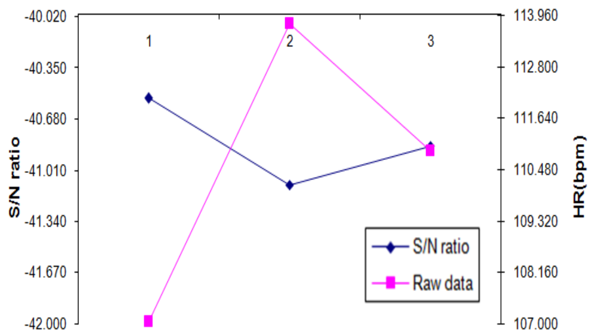


**Fig 5 shows the effect of worker on HR**

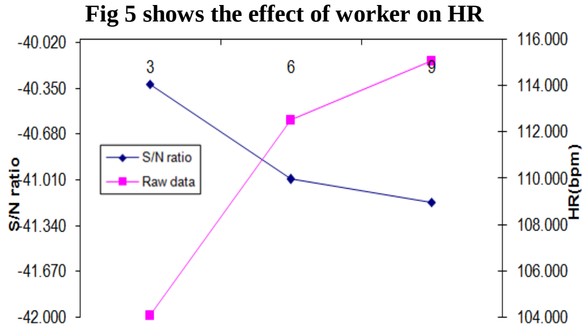


**Fig 6 Shows the effect of frequency on HR**

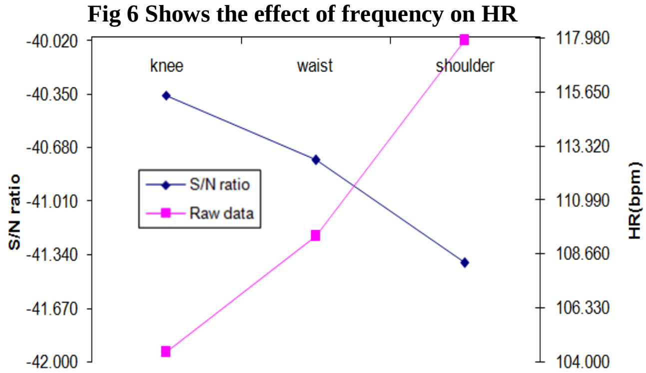

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**Fig 7 Shows the effect of vertical distance on HR**

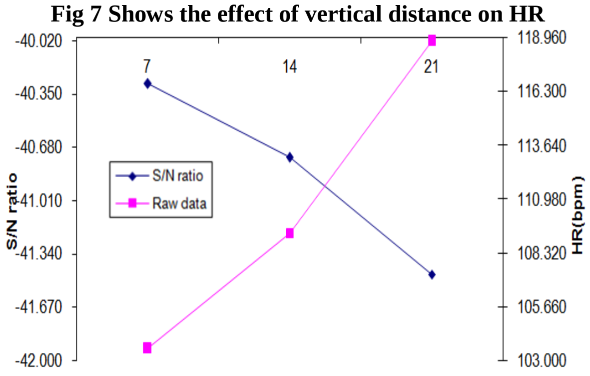


**Fig 8 shows the effect of load on HR**

**Table 9. Shows the orthogonal array for L18 with response (raw data & S/N ratio) for HR**

| Input parameters | | | | | | | Responses | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| A | B | C | D | E | F | G | Raw Data | | | S/N Ratio |
| Exp No. | Belt | Box grip | Worker | Frequency | Vertical distance | Load | Heart Rate | | | (dB) |
| | | | | | | | R1 | R2 | R3 | |
| 1 | no belt | without handle | 1 | 3 | knee | 7 | 92.4 | 92.9 | 93.3 | -39.36 |
| 2 | no belt | without handle | 2 | 6 | waist | 14 | 117.3 | 117.8 | 118.4 | -41.42 |
| 3 | no belt | without handle | 3 | 9 | shoulder | 21 | 135.4 | 135.3 | 136.1 | -42.64 |
| 4 | no belt | with handle | 1 | 3 | waist | 14 | 93.2 | 93.9 | 94.3 | -39.44 |
| 5 | no belt | with handle | 2 | 6 | shoulder | 21 | 127.4 | 127.8 | 128.2 | -42.13 |
| 6 | no belt | with handle | 3 | 9 | knee | 7 | 97.4 | 97.8 | 98.2 | -39.81 |
| 7 | no belt | with slot box | 1 | 6 | knee | 21 | 106.2 | 106.6 | 107.1 | -40.56 |
| 8 | no belt | with slot box | 2 | 9 | waist | 7 | 105.1 | 105.7 | 106.3 | -40.48 |
| 9 | no belt | with slot box | 3 | 3 | shoulder | 14 | 104.2 | 104.7 | 105.3 | -40.4 |
| 10 | belt | without handle | 1 | 9 | shoulder | 14 | 120.5 | 121.2 | 121.7 | -41.67 |
| 11 | belt | without handle | 2 | 3 | knee | 21 | 110.1 | 110.8 | 111.4 | -40.89 |
| 12 | belt | without handle | 3 | 6 | waist | 7 | 106.2 | 107.1 | 107.8 | -40.59 |
| 13 | belt | with handle | 1 | 6 | shoulder | 7 | 107.6 | 108.3 | 108.9 | -40.69 |
| 14 | belt | with handle | 2 | 9 | knee | 14 | 110.3 | 110.8 | 111.3 | -40.89 |
| 15 | belt | with handle | 3 | 3 | waist | 21 | 112.1 | 112.7 | 113.2 | -41.03 |
| 16 | belt | with slot box | 1 | 9 | waist | 21 | 118.9 | 119.4 | 120.1 | -41.54 |
| 17 | belt | with slot box | 2 | 3 | shoulder | 7 | 109.8 | 110.3 | 109.1 | -40.81 |
| 18 | belt | with slot box | 3 | 6 | knee | 14 | 107.3 | 107.6 | 107.9 | -40.64 |

The average value of the raw data and S/N ratio for parameter at level L1, L2 and L3 are calculated and are given in Table 5 and 6 respectively. The pooled versions of ANOVA of the raw data and S/N ratio for HR are given in Table 7 and 8. Figure 3 and Figure 4 shows that Back belt and box grip respectively are the significant parameter affecting the box without suitable grip. On the other side, when we hold a box with handle grip or with slotted grip the heart rate does not increases significantly, the reason is less effort is required to lift the box due to suitable and easy grip. More value of Heart is determined at position where back belt is not used shown in Figure 3 and more value of Heart rate is calculated where the worker use Box without handle grip and minimum value calculated at where the worker use Box with slotted grip but the Heart Rate value is recorded slightly greater at where worker use Box with handle grip Shown in Figure 4. In other parameters like Frequency the value of HR is maximum at 9 and minimum at frequency 3 Shown in Figure 6. With vertical distance at shoulder the HR is high and minimum HR is recorded at knee position Shown in Figure 7, at 21 kg load HR is maximum and minimum at 7 kg load Shown in Figure 8.

## VII. ESTIMATION OF OPTIMUM PERFORMANCE CHARACTERISTICS FOR HR

The optimum value of HR was predicted at the selected levels of significant parameters A1, B1, C1, D1, E1 and F1. The estimated mean of the response characteristics HR is determined (Ross 1988; Roy 1990) as

$\mu_{HR}$ = A1+B1+C1+D1+E1+F1-5T

Where T: Overall mean of HR = 110.5685, A1 = minimum HR at Back belt condition, B1 = minimum HR at Box grip, C1 = minimum HR with worker, D1 = minimum HR at frequency, E1 = minimum HR at vertical distance, F1 = minimum HR at load (Ref. to table 6 and Figure 3-8) Substituting the values of various terms in the above equation $\mu_{HR}$ = 109.196+108.522+107.028+104.094+104.411+103.567-5x110.5685 $\mu_{HR}$ = 83.9755

7 kg load (level1) and 25cm horizontal distance.

The predicted optimal range for HR is $CI_{CE}$:

80.45< $\mu_{HR}$<87.50. The 95% confidence interval of the predicted mean for HR is $CI_{POP}$: 81.76< $\mu_{HR}$<86.21. The Confirmation to be 83.62.

The 95% confidence interval of confirmation experiments ($CI_{CE}$) and of population ($CI_{POP}$) is calculated by using the following equations

$$CI_{CE} = \sqrt{F\alpha\,(1, fe\,)Ve[1/neff + 1/R]}$$

$$CI_{POP} = \sqrt{\frac{F\alpha(1, fe)\,Ve}{neff}}$$

Where $F_\alpha$ (1, fe): The ratio at the confidence level of (1-α) against DOF 53 and error DOF fe = 42; N: The total number of results = 54(Treatment = 18, Repetition = 3), R: Sample size for confirmation experiments =3; Ve: Error varience =5.5092, fe error DOF = 42 N efficiency = N/1+ [DOF associate in the estimate of mean response] = 54/1+11 =4.5 F0.05 (1, 42) = 4.076 t (tabulated F value), So $CI_{CE}$ = ±3.527,$CI_{POP}$ ±2.234.

The predicted optimal range (for a confirmation runs of three experiments) is: $\mu_{HR} - CI_{CE} < \mu_{HR} < \mu_{HR} + CI_{CE}$; $80.45 < \mu_{HR} < 87.50$. The 95% conformation interval of the predicted mean is as follows:

$\mu_{HR} - CI_{POP} < \mu_{HR} < \mu_{HR} + CI_{POP}$; $81.74 < \mu_{HR} < 86.21$

The optimal value of process parameters for the predicted range of optimal HR was as follows: Condition Back belt condition as compared to No Back belt condition and also less in Box with slotted grip as compared to Box without handle grip. Other facts found in experiment are given below.

- The optimum levels of parameters for HR are: Back belt (level 1), Box grip (level 1), first worker (level 1), up to knee Frequency (level) of Belt (A, 1st level) = with Back Belt, Box (B, 2nd level) = Slotted grip, Worker(C, 1st level) = 1, Frequency (D, 1st level) = 3, Vertical distance (E, 1st level) = knee distance, Load (F, 1st level) = 7 kg, Horizontal distance = 25cm.

## VIII. CONCLUSION

In this study we found that Box grip and Back belt plays an important role in lifting a box. If the Back belt and Box with slotted grip is used during manual material handling then we can minimize the increased value of HR and $VO_2$. It can be seen in Figure 3 and 4 that the value of HR is less in case

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