An Ergonomic Evaluation of a Job (Engine Mounting on Frame Body) In an Automobile Industry with Post Counter Measure Assessment Study

Abstract

**Introduction & Objective:** Even after automated industrial operations, manual handling is still evident with development of physiological fatigue along with ergonomic risk factors which invariably reduces human performance capacity. A cross-sectional scientific study was conducted in an automobile industry to assess physiological strain & ergonomic risk factors with an aim to make job comfortable & less risky.

**Method:** Study was conducted on 8 randomly selected employees of frame assembly section in an automobile industry. Job was manual unloading of automobile engine weighing 30 kg from conveyor tray, carrying it to another conveyor 2 meter apart & mounting on frame body. Resting HR, BSA & BMI of the workers were computed. Peak HR, oxygen saturation & later, recovery HR was recorded. NIOSH lifting index (LI) & RULA score for postural stress were assessed.

**Result:** Work-site dimensions of conveyor tray carrying engines- vertical height 52 cm from ground, horizontal distance 15 cm & frequency approx. 3/ min. Physiological work stress assessment (peak heart rate, oxygen uptake & energy expenditure) were 129.5±7.07 beats/min, 1.27±0.15 lit/min & 6.42±0.71 kcal/min respectively. Physiological recovery was 98.95±11.47, 91.10±10.23 & 83.70±7.35 beats/min. Mean oxygen saturation was 98.12% & mean resting heart rate 74.63 beats/min. LI was 4.04±0.53 and mean postural stress through RULA score was assessed to be 4.55±0.42

**Conclusion:** Physiological strain and postural strain were high. The cause of high RULA score & LI could be ascertained to job at shoulder height; vertical factor of LI was primarily responsible for which recommendation was conveyed for worksite design modification (subsequently done & recorded).

**Keywords:** NIOSH lifting index, RULA, Physiological strain parameter, physiological recovery status, mechanical manipulator.

**Introduction**

High skill engineering operations require physical involvement of individuals even though most of the automobile industries are semi-automated. But the truth is, still, manual handling is evident in almost all operations to a significant extent. Physical involvement of individual may causedevelopment of complex physiological fatigue which in turn reduces human performance capacity. Physiological fatigue can be assessed.
accurately by studying various physiological parameters as well as it can be managed well at shop floor through some minor or major interventions. Similarly the ergonomic risk factor also restricts performance of operators, even at times, causing accidents. In this context, work physiology techniques are used worldwide to make human labour comfortable, productive and safe at workplace. This present study was carried out in an automobile industry to assess physiological strain and ergonomic risk factors with a view to make job more comfortable & with less effort and minimum risk at shop floor. There was also a provision for proposal of counter-measures, if adverse results were detected with scope of assessment study, post counter measure implementation.

Material & Methods

Time and location

The study was carried out in an automobile industry in frame assembly section during the morning shift from 06 AM to 2-00 PM each day for 5 days’ duration. The usual job protocol of operators was followed with rest periods, lunch breaks to get a complete authentic picture of their job profile.

The subjects

The subjects were the regular employees of the organization. Their physical characteristics and work experience, Body mass index (BMI) have been presented in table no-1.

<table>
<thead>
<tr>
<th>Physical characteristics of study subjects</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
<th>ZSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in years</td>
<td>23.99</td>
<td>21.88</td>
<td>26.42</td>
<td>1.55</td>
</tr>
<tr>
<td>Height in cm</td>
<td>165.83</td>
<td>156.04</td>
<td>174.43</td>
<td>5.48</td>
</tr>
<tr>
<td>Weight in kg</td>
<td>58.47</td>
<td>51.88</td>
<td>64.21</td>
<td>4.72</td>
</tr>
<tr>
<td>Body surface area in sq. m.</td>
<td>1.62</td>
<td>1.33</td>
<td>1.88</td>
<td>0.17</td>
</tr>
<tr>
<td>Body mass index</td>
<td>21.26</td>
<td>18.64</td>
<td>23.01</td>
<td>1.58</td>
</tr>
<tr>
<td>Years of experience</td>
<td>2.92</td>
<td>0.58</td>
<td>6.5</td>
<td>2.04</td>
</tr>
</tbody>
</table>

After motivating all the concerned shop floor workers through counselling for full cooperation, eight young volunteers were selected for study from frame assembly section. The study was carried out during actual industrial operations without disturbing normal work schedule of plant.

Job Description

Job studied was: Unloading of automobile engine from conveyor stack to mount it on frame body. This operation was carried out manually by one operator for unloading and fixing them onto frame body by the same operator. Conveyor movement time is pre-set in such a way that just adequate time is available to operator for finishing job, one tray after another. Operation continues till conveyor is stopped either by mechanical failure or till time schedule is over. Each engine is 28 to 32 kg in average weight which they handle manually.

Field Investigation

The ergonomic evaluation of the operation (unloading of engine from conveyor to mount onframe body) has been done with standard physiological measurements. All subjects were allowed to take rest for twenty min after arrival at shop floor. Resting heart rate was taken from radial pulse by counting time taken for ten beats (1, 2). The body surface area of the operator was computed from nomogram of Sen & Banerjee (10). The Body mass index was calculated from weight in kg/ height in meter sq. After recording resting heart rate, volunteers were allowed to start their work. After every conveyor tray was unloaded completely, their peak working heart was recorded and portable pulse oximeter was used to record oxygen saturation and peak working heart rate, besides manual recording. The subjects were not allowed to sit until recovery heart rate was recorded after one min. rest in standing posture. The recovery heart rate response was recorded from 1 to 1.5, 2 to 2.5; 3 to 3.5 min, recorded manually from carotid pulse after completion of each job. The simple portable pulse oximeter was used for recording the oxygen saturation status by placing photo cell on index finger of subject after completion of job in standing posture and the value was recorded from display of the machine and presented in
table-03. The work dimensions were taken by using a simple steel tape.

The vertical height of operation was 52 cm from ground, distance carried was 50 cm & horizontal placement distance was 15cm. Each conveyor tray stack was conveying 6 engines which took two min to unload, thus frequency is three min-1. NIOSH’S lifting equation was used for assessing ergonomics risk factor; lifting index was computed by actual weight carried in kg / Recommended weight lift in kg to assess physiological strain incurred during operation (3). The postural stress was assessed through Rapid upper limb assessment (RULA) techniques, for each operator, through RULA work sheet (4). The RULA action limits are: 1 or 2- acceptable/ no risk, 3 or 4- further investigation is recommended, change may be required, 5 or 6-indicate investigation/ changes are required soon, 7-Indicates investigation/ changes are required immediately. As per RULA score, appropriate action limit was considered for decision.

**Results**

The Physical characteristics of the experimental volunteers have been presented in table no-01. The mean age was found to be 23.99±1.59 years. The mean height and weight was found to be 165.83±5.48 cm and 58.47±4.72 kg respectively. Age, height, weights correlated well with the physiological maturity of working population. The years of experience were just 2.92±2.04 years. The surface area of the body of operator and their Body mass index did not show any tendency of obesity.

Table No-02 shows the lifting index computed through NIOSH Revised lifting equation.

All the factors were recorded in field and appropriate multipliers were recorded from multiplier chart. The postural discomfort in terms of RULA score has also been presented in Table-02.

### Table 2. Postural Stress by RULA Score & Revised NIOSH Lifting Index

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
<th>2SD</th>
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</thead>
<tbody>
<tr>
<td>RULA Score</td>
<td>4.55</td>
<td>4</td>
<td>5</td>
<td>0.42</td>
</tr>
<tr>
<td>Revised NIOSH Lifting Index</td>
<td>4.04</td>
<td>3</td>
<td>4.8</td>
<td>0.53</td>
</tr>
</tbody>
</table>

The Physiological work stress\(^6,7\), was assessed from peak working heart rate and presented in table no-3.

### Table 3. Physiological strain parameters of study subjects

<table>
<thead>
<tr>
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<th>Mean</th>
<th>Min</th>
<th>Max</th>
<th>2SD</th>
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</thead>
<tbody>
<tr>
<td>Mean Resting Heart Rate (bpm)</td>
<td>74.63</td>
<td>70</td>
<td>78</td>
<td>2.67</td>
</tr>
<tr>
<td>Working Heart Rate (bpm)</td>
<td>129.5</td>
<td>120</td>
<td>140</td>
<td>7.07</td>
</tr>
<tr>
<td>Oxygen Uptake (lt/min)</td>
<td>1.27</td>
<td>1.1</td>
<td>1.5</td>
<td>0.15</td>
</tr>
<tr>
<td>Energy expenditure (kcal/min)</td>
<td>6.42</td>
<td>5.5</td>
<td>7.5</td>
<td>0.71</td>
</tr>
<tr>
<td>Oxygen saturation (%)</td>
<td>98.12</td>
<td>96.99</td>
<td>99.22</td>
<td>0.73</td>
</tr>
</tbody>
</table>

The oxygen up take in lit.min\(^{-1}\), concomitant energy expenditure in Kcal min\(^{-1}\) was computed from peak working heart rate. All subjects had done the job in same sequential conveyor in same posture; after completion of each operation cycle, physiological measurements were recorded immediately after cessation of work. Assessment of job was done through peak heart rate, oxygen uptake, and energy expenditure. The Recovery Heart rate response of the operators was also recorded after one min rest in standing posture for 1 to 1.5, 2 to 2.5, 3 to 3.5 min of cessation of work and presented in table no-04.

### Table 4. Physiological Recovery status

<table>
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<th>Mean</th>
<th>Min</th>
<th>Max</th>
<th>2SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Min Recovery HR (beat count)</td>
<td>98.95</td>
<td>86</td>
<td>118</td>
<td>11.47</td>
</tr>
<tr>
<td>Second Min Recovery HR (beat count)</td>
<td>91.1</td>
<td>78</td>
<td>110</td>
<td>10.23</td>
</tr>
<tr>
<td>Third Min Recovery HR (beat count)</td>
<td>83.7</td>
<td>74</td>
<td>98</td>
<td>7.35</td>
</tr>
</tbody>
</table>
The nature of recovery was used for assessing the physical fitness status of the operators. The normal recovery of heart rate between first and second readings must be more than 10 beats & is then considered as normal recovery and good cardiovascular adaptation.

**Discussion**

It could be seen from table No-1 that the physical status of the operators were recorded as physically active & physically fit to do the job assigned to them. The operators were active in their performance. This was because they were regular operators having good physique as shown from their physical characteristics. The mean postural stress was found to be about 4.55±0.42. RULA score action limits suggested that further investigation and changes were required soon. Thus we suggested redesigning the job which in turn will reduce RULA score to acceptable limit. Similarly when we consider the lifting index it was found to be 4.4 ± 0.53; considered to be in high risk category. Thus immediate action was suggested to reduce risk factor from shop floor. The real cause of high RULA & LI was because the job was at shoulder height which contributed to such high value of RULA & LI. Accordingly suggestion was given to manage ment for redesigning the job. The vertical factor, in particular, was contributing to high LI value because of shoulder level job. The mean Resting heart rates of the operators were found to be 74.63±2.67 beats min⁻¹ after twenty min rest. The physiological work stress through peak heart rate beats min⁻¹, oxygen uptake lit min⁻¹, energy expenditure Kcal min⁻¹ was found to be 129.5±7.07, 1.27±0.15, 6.42±0.71 respectively; suggested that present job was of high category. The Oxygen saturation was also found to be having normal mean of 98.99%; suggested better cardiovascular adaptation among operators. The Physiological recovery reactions (table no-04) for first, second and third minute were found to be 98.95±11.47, 91.10±10.23, 83.70± 7.35 respectively. This recovery heart rate counts were showing normal recovery, suggesting that operators were physically fit because of their daily industrial operation as well as good physical status.

**Conclusion**

The study concluded with the following inferences: The postural strain in terms of strain index was high- some action was recommended in form of job redesigning. However, the postural strain in terms of action limits of RULA was not so high; however it will reduce once redesigning of tray is introduced/ job is redesigned. Hence recommendation was given for redesigning of the conveyor stack. The conveyor stack had 2 rows, one upper (at shoulder height)- (Figure 1) conveying 2 engines & one lower row (at waist height) conveying 4 engines.

Recommendation was placed for eliminating the upper row & adding the 2 upper row engines in the lower row along with 4 engines (Figure 2). The suggestion was given due respect & PDCA (Plan, do, check, act) cycle was ensured with the outcome of a manipulator (Figure 3) installation for lifting the upper row engines.

The priorly suggested recommendation could not be implemented due to lack of space at the working zone which hindered the expanded lower row movement of conveyor stack. But by using the electrically operated manipulator, the actual weight lifted approached almost zero.

After making a fresh assessment study post counter measure implementation, it was found that the NIOSH revised LI approached zero from the previous unacceptable value of 4.4±0.53. Thus, the study helped to detect & provide successful implementation of workplace design modification for an occupational health issue.
Figure 1. Lifting of engine from stack at shoulder height

Figure 2. Modification plan
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Conflict of Interest: Nil

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