Original Article

Ergonomic Behaviors Analysis in an Iranian Petrochemical Company Using The ELECTRE Method

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Objectives: This study aimed to evaluate and analyze the ergonomic behaviors order to select the best work shift group in an Iranian petrochemical Company, in 2010.

Methods: The methodology was based on the Ergonomic Behavior Sampling (EBS), and performed using ELECTRE method. In this study 1147 behaviors were observed.

Results: The results indicated that 43.6% of workers' behaviors were unergonomic. The most frequent unergonomic behavior was amusing of legs while load lifting with 83.01% of total unergonomic behaviors observations. Using ELECTRE method, most effective shift group and least attractive alternatives for intervention were selected in the company.

Discussion: Findings declare high number of unergonomic behaviors. Catastrophic consequences of accidents in petrochemical industry necessitate paying more attention to workers' ergonomic behaviors in the workplace.

Keywords: Ergonomic behavior, Ergonomic Behavior Sampling, ELECTRE

Introduction

Every organization contains some main components like equipment, environment, and people (1). Therefore, for reaching to continuous improvement at workplace and generally at organization management, we should pay more attention to each component and try to control them.

The most important asset of an organization is its employees. But, these valuable assets can make accidents for themselves or other people and properties at work. Therefore, monitoring of them, especially their behaviors, is very important during the work.

Ergonomic behavior

There is no specific definition in the literature for "ergonomic behavior". However, we can adopt safety behavior definition that has been presented in "a practical guide for behavioral change in the UK oil and gas industry (2) for ergonomic behavior. This definition is: "A behavior that is directly related to Ergonomics, such as correct manual handling, having correct posture or talking to colleagues about ergonomics."

In fact, ergonomic behavior is applying ergonomic principles that prevent musculoskeletal disorders or traumatic cumulative disorders. For example, lifting with correct weight and closing objects to the body while lifting. Findings of McSween (3) suggest that in most organizations at risk behavior contributes to between 86 and 96 percent of all injuries. These data do not suggest that employees are guilty for %96 of their injuries. From the standpoint of behavioral psychology, behavior is a function of environment in which it occurs. Unsafe work behavior is accordingly the result of (1) the physical environment, (2) the social environment, and (3) workers' experience (3).

The expenses of musculoskeletal disorders were estimated to be %1/13 of the governmental budget in 2000 in Iran (4). Therefore, the importance of attention to ergonomic behavior is obvious.

First, we showed that our objective behaviors are accepted as behavior in the literature. Manual handling (1, 5) and manual lifting (3, 4, 6-8) were recognized as a work behavior. Moreover, manual lifting components such as closing the load to body, correct weight while lifting and schedule of lifting

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and appropriate grip all were considered as behaviors (1, 3). Posture of worker is one of the most important subjects in the workplace known as behavior (1, 4, 8-10). In addition, elements of posture such as elbow bending and trunk twisting are also known as behavior (3, 11).

Material and Methods

This cross-sectional study was conducted by using Ergonomic Behavior Sampling (EBS) technique based on Safety Behavior Sampling (SBS), and by Entropy method. Furthermore, the relationships between Ergonomic Behavior and employees' demographic characteristics such as age, education, job experiences, number of trainings and marriage status were examined by statistical analysis tests of t-test, ANOVA and Pearson correlation. In order to gather general data about workers, a demographic questionnaire was used.

Our statistical population was all of the workers in functional units of Khuzestan Petrochemical Company (KPCo). All of the observed workers were within 5 work shift groups day shift or No, A, B, C, D). Day shift day group works all of weekdays at 8-17 o'clock but shift work groups (A, B, C, D) work at three times in week (from 6 am until 14 am, 14-22, and 22-6) rotationally. Their jobs were identical.

Procedure for Ergonomic Behavior Sampling

Work Station Definition

It means identification of the department in an organization where ergonomic behavior sampling was going to be conducted. In this study, a workstation considered as a functional unit of KPCo in Iran.

Preparing a List of Unergonomic Acts

After specifying unergonomic behavior as any action with harmful consequences, a list of unergonomic acts was collected. The obtained list was adjusted based on literature review and specific conditions in our study such as the nature of the job, reviews of accident reports, and present cultural conditions. Table 1 shows a specimen worksheet.

Table 1. Ergonomic Behavior Checklist

Behavior	Ergonomic	Unergonomic	notices
Proper carrying Load weight			
Load closed to body while carrying			
Proper grip of load while carrying			
Carrying from appropriate path			
Symmetric carrying			
Distance of carrying (4 meters)			
Proper lifting load weight			
Move feet - don't twist while lifting			
Proper grip of load while lifting			
Load closed to body while lifting			
Use of legs while lifting			
Upper arm posture			
Leg posture			
Trunk posture			
Lower arm posture			
Wrist posture			
Neck posture			

Conducting Pilot Study

After specifying the unergonomic behaviors, a special number of necessary observations of workers' behaviors were carried out in order to determine the proportion of their unergonomic behaviors. The number of required observations was based on the data collected during the pilot study, the accuracy required, and the given level of confidence. Two special numbers were recorded during the pilot study:

1. Total number of observations (N1)
2. Number of observations in which unergonomic behavior was observed (N2)

Thus, the proportion of unsafe behavior is as Eq. 1 (4, 8, 12). If: e = desired accuracy, N = Total number of observations required and $Z_{0.99}$= the value obtained from standardized normal tables for a given level of confidence.

$$p=\frac{N_2}{N_1} \qquad \text{Eq. (1)}$$

Then the total number of required ergonomic behavior observations calculated by Eq.2.

$$N=\frac{[Z^2_{1-\alpha}P(1-P)]}{e^2} \qquad \text{Eq. (2)}$$

Accuracy may be interpreted as the tolerance limit of the observations that fall within a desired confidence level. 5% accuracy with 99% confidence level is the combination often used in ergonomic behavior sampling. This means that 99% of the time within 5% accuracy limit, the conclusion drawn based on ergonomic behavior sampling will be representative of the actual population.

Calculation of Required Number of Observations

After performing pilot study, the proportion of unergonomic acts was estimated to be about 47.7%. With 5% accuracy and 99% confidence level, the total number of observations was estimated to be near 900.

Ergonomic behavior sampling had to be done randomly. It is accomplished when each period of observation during the work day is selected by the same chance. So in the next step the observations are performed randomly. It means that both observed workers (134 workers of work units) and frequency of observations (in the period of 8 hours from 8 to 17) were selected randomly. Since the behavior of human being might change from time to time, the observation duration has a critical role in the accuracy of the results. This duration should be as short as possible to observe and specify the behaviors. In this research, the average time of each duration was 3 seconds. Unergonomic behaviors were carefully recorded in a limited time of 3 seconds. The researcher carried out the observations randomly while the subjects were not aware of the fact that they were being observed. In order to recognize the relationship between the employees' demographic characteristics and unergonomic behaviors, previously mentioned variables such as age, work experience, education, working shift and marriage status were registered through interviews and a special questionnaire.

ELECTRE[1]

An important advantage of using outranking methods (e.g., ELECTRE methods) is that they are able to take just ordinal scales into account, without needing to convert the original scales into abstract ones with an arbitrary imposed range; thus maintaining the original concrete verbal meaning (13).

The ELECTRE method based on interval numbers takes the following steps (14):

Step 1. Calculating the normalized decision matrix from decision matrix and Eq.3.

$$n_{ij}=\frac{r_{ij}}{\sqrt{\sum_{i=1}^{m} r_{ij}^2}} \qquad \text{Eq. (3)}$$

Step2. Calculating the weighted normalized decision matrix. Making use of the known weights vector and normalized decision matrix (Eq. 4).

$$V=N_D.W_{n\times n} \qquad \text{Eq. (4)}$$

$$W=\{w_1,w_2,...,w_n\}$$

$$\approx(\text{consider as a duty of Decision Ma ker})$$

Weighted normalized decision matrix = V

$$=N_D.W_{n\times n}$$

$$=\begin{vmatrix} V_{11,...} & V_{1j,...} & V_{1n} \\ \vdots & \vdots & \vdots \\ V_{m1,...} & V_{mj,...} & V_{mn} \end{vmatrix}$$

Step 3. Determining the concordance and discordance set. For each pair of alternatives k and l, k, l=1,2,...,m ; l≠ k, the set of decision attributes J={j| j=1,2,…,n} is divided into two distinct subsets: The concordance set (Skl) and discordance set (Dkl) of Ak and Al. Determine the concordance and discordance set (Skl and Dkl). Skl = {j | rkj ≥ rlj}. The complementary subset is called discordance set, which is:

$D_{kl}=\{\, j \mid r_{kj} < r_{lj} \,\} = J - S_{kl}$

Step 4. Calculating the concordance index and establish the concordance matrix (table 2) by Eq. 5.

$$l_{k,l}=\sum_{j\in S_{k,l}} w_i \Big/ \sum_{j=1}^{n} w_i \qquad \text{Eq. (5)}$$

Table 2. Concordance matrix

$$I=\begin{vmatrix} - & I_{1,2} & I_{1,3} & .... & I_{1,m} \\ I_{2,1} & - & I_{2,3} & .... & I_{2,m} \\ . & . & - & .... & . \\ . & . & . & - & . \\ I_{m,1} & I_{m,2} & .... & I_{m,(m-1)} & - \end{vmatrix}$$

1- Elimination Et Choice Translating Reality

The concordance index reflects the relative importance of A_k with respect to A_l.

Step 5. Calculating the discordance index and establishing the discordance matrix. For decision making problem with real number attributing values, the discordance index can be calculated by Eq. 6.

$$NI_{k,l} = \frac{\max | V_{kj} - V_{lj} |_{j \in D_{k,j}}}{\max | V_{kj} - V_{lj} |_{j \in J}} \qquad \text{Eq. (6)}$$

According to above mentioned formula, calculate all alternatives' discordance indices, and then set up matrix NI (table 3).

Table 3. Discordance matrix

$$NI = \begin{vmatrix} - & NI_{1,2} & NI_{1,3} & .... & NI_{1,m} \\ NI_{2,1} & - & NI_{2,3} & .... & NI_{2,m} \\ . & . & - & .... & . \\ . & . & . & - & . \\ NI_{m,1} & NI_{m,2} & .... & NI_{m,(m-1)} & - \end{vmatrix}$$

Step 6. Determining the concordance dominance matrix. This matrix can be calculated by concordance index and a parameter ($\bar{I}$), this parameter can be calculated as Eq. 7.

$$\bar{I} = \sum_{k=1}^{m} \sum_{l=1}^{m} I_{k,l} \; / \; m(m-1) \qquad \text{Eq. (7)}$$

Then through comparing all elements in concordance matrix and the value of ($\bar{I}$), the concordance dominance matrix F can be established; the elements of which are defined as:

$$f_{k,l} = 1 \qquad \text{if} \rightarrow \quad I_{k,l} \geq \bar{I}$$

$$f_{k,l} = 0 \qquad \text{if} \rightarrow \quad I_{k,l} < \bar{I}$$

Step 7. Determining the discordance dominance matrix. This matrix can be established by discordance index and a parameter ($\overline{NI}$), ($\overline{NI}$) can be calculated by Eq. 8.

$$\overline{NI} = \sum_{k=1}^{m} \sum_{k=1}^{m} I_{k,l} / m(m-1) \qquad \text{Eq. (8)}$$

Through comparing all elements in discordance matrix and the value of ($\overline{NI}$), the discordance dominance matrix G can be established; the elements of which are defined as:

$$g_{k,l} = 1 \qquad \text{if} \rightarrow \quad NI_{k,l} \geq \overline{NI}$$

$$f_{k,l} = 0 \qquad \text{if} \rightarrow \quad NI_{k,l} < \overline{NI}$$

Step 8. Determining the aggregate dominance matrix. The aggregate dominance matrix:

$$h_{k,l} = f_{k,l} \cdot g_{k,l}$$

Step 9. Eliminating the inferior alternatives. While the outranking relationship has been constructed, the less favorable alternatives can be eliminated, and then we get a non-inferior solution set. The dominated alternatives can be easily identified in the H matrix, and we simply eliminate any column(s) which have an element of 1.

Results

All workers were male. Average employees' age was (30.95±5.298) years old and, 63.6% of them were married. Regarding the education, the employees with diploma or lower levels of education had the largest proportion by 38.8%. The employees with M.Sc. or higher levels were allocated to the least portion by 3.7%. The results of these demographic characteristics are shown in table 4. The results also signified that the average work experience was (6.57±4.44) years. In average, every worker attended five safety training courses but the range varied from 1 to 20 courses.

Table 4. Individual job unit, Education level and Shift work group frequencies

Variable	alternatives	percentage
Job unit	operating	73.1
	maintenance	11.2
	Technical services	9.7
	storage	6.0
Education level	Diploma or less	38.8
	Junior college diploma	20.9
	Bachelor	36.6
	Master or higher	3.7
Shift work group	A	15.7
	B	16.4
	C	20.1
	D	17.9
	Working day	29.9

Reliabilities of ergonomic target behaviors checklist (ETBC)

Checklist's reliability was 87%, assessed by comparing of six different persons' responses who completed ETBC for identical data and calculating percentage of similar responses, so its reliability was desirable (6).

Ergonomic behaviors results

The results indicated that 43.6% of workers' behaviors were unergonomic out of total number of 1147. Among unergonomic acts, the most frequent unergonomic behaviors were amusing of legs while load lifting with 87% of total unergonomic behaviors observations on the other hand, carrying load with correct weight was only about 0.042% of unergonomic behaviors of total observations which was the best condition. Results did not declare any significant relationship between ergonomic behavior percentage and demographic characteristics ($p>0.05$).

Results Based on Applying ELECTRE Method

In this study 17 ergonomic behaviors (n=17) in five shift work groups (m=5) were assessed. Table 5 shows decision making matrix which contains ergonomic behaviors frequencies for each work shift group.

Table 5. Decision making matrix (Frequencies of each unergonomic behavior in shift work groups)

E.B. / Shift Group	carrying Load weight	load closed to body while carrying	use of legs while lifting	move feet - don't twist while lifting	grip of load while lifting	neck pos.	upper arm posture	lower arm pos.	wrist pos.	trunk pos.	leg pos.	Lifting load weight	load closed to body while lifting	distance of carrying	grip of load while carrying	path of carrying	symmetric carrying
A	0	2	5	0	0	22	28	26	28	24	14	1	3	4	0	2	3
B	1	6	8	2	2	24	32	37	24	38	22	0	1	3	2	3	2
C	6	6	10	5	5	30	36	30	31	32	25	0	0	1	1	0	1
D	4	7	10	6	7	34	31	33	33	33	27	0	0	3	3	2	2
NO	1	8	11	2	7	40	59	50	46	52	34	0	2	3	2	3	4

For conducting ELECTRE method we had to weight each ergonomic behavior as an input datum to this method algorithm. According to the results of entropy, weights of ergonomic behaviors are in this way: carrying load, 0.370; load close to the body while carrying, 0.138; lifting load, 0.1113; move feet-don't twist while lifting, 0.0784; grip of load while lifting, 0.0720; grip of load while carrying, 0.0662; carrying path (moving in safe paths), 0.056; symmetric carrying, 0.0211; distance of carrying, 0.017; load close to the body while lifting, 0.016; using of legs while lifting, 0.013; upper arm posture, 0.0096; leg pos. 0.0085; trunk pos. 0.0074; lower arm pos. 0,0059; wrist pos. 0.0055; and neck pos. 0.0052.

After determination the concordance dominance matrix and the discordance dominance matrix, then we determined the aggregate dominance matrix as shown in table 6.

Table 6. Aggregate dominance matrix

$$H=\begin{array}{c|ccccc} & A & B & C & D & No \\ A & - & 0 & 0 & 0 & 0 \\ B & 1 & - & 0 & 1 & 1 \\ C & 0 & 0 & - & 1 & 0 \\ D & 0 & 0 & 0 & - & 0 \\ No & 1 & 0 & 0 & 0 & - \end{array}$$

Finally, we eliminate the inferior alternatives as figure 1.

By this step we could realize that working shift group B was the most effective and working shift groups A and D were the least attractive alternatives for selection.

So, B, C, day shift (No), D and A groups were first, second, third, and fourth rank of importance, respectively.

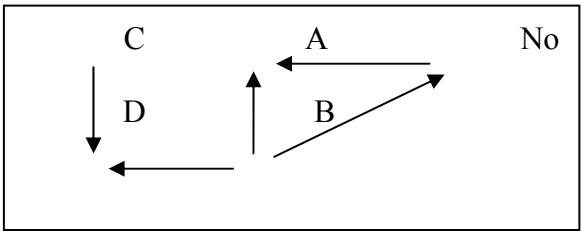

Figure 1. Influence of alternatives on the others for eliminating the inferior alternatives

Conclusion

Considering catastrophic consequences of accidents in petrochemical industry, the results showed the importance of attention to prevention principles and decreasing employees' unergonomic behaviors. This approach results in reduced injuries and accidents costs of KP Co. In order to achieve that result, we can focus on these behaviors: carrying load with correct weight, taking load closer to the body while carrying, and lifting load with correct weight, because these behaviors are located at first, second and third priorities according to their weight, respectively. Condition for better and sustainable improvement in ergonomic behaviors of company will be achieved by more attention to those behaviors. Moreover, ELECTRE method's results reveal priority of correct actions should be considered as groups with lower importance. Hence, A, D and Day shift (No) groups should be at high priorities for correcting actions. In other words, we cannot neglect physical and social conditions and management's behavior effects on workers' behavior forming in the workplace (3).

Also, some effective components have been approved for improving safety in process industries as follows (3):

- A behavioral observation and feedback process
- Formal review of observation data
- Improving goals
- Reinforcement for improvement and goal attainment

These criteria showed importance of considering workers' behaviors at workplace for promoting comfort, safety and productivity in the organization. Thus, behavior observation and feedback must be done at the KPCo on time and scheduled. Finally, ABC[1] model (15) application can help for improving ergonomic behaviors. By activators such as ergonomics meetings, goal setting, rules and regulations we can improve behaviors directly. In the other hand, consequences such as self-approval, reprimand, peer approval, penalty, feedback and injury can improve behaviors by motivation.

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1- Activators-Behaviors-Consequences