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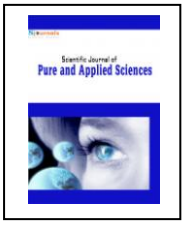

Original article

Design of the evaluation model for total ergonomics interventions with fuzzy approach

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ABSTRACT

The present study describes the development of a theory for the guidance of ergonomic interventions (EI) and evaluation processes with the help of fuzzy approach. The study was carried out at an educational center (EC) with the micro- and macro-ergonomic interventions. The combined results of both interventions have demonstrated the positive effects of these techniques in increasing the productivity and reducing the musculoskeletal disorders (MSDs). So, the overall annual performance of the educational center had a significant rise in terms of lower costs, increased revenue and work expansion with less human force. Analysis of questionnaire data "body mapping" with the fuzzy approach has shown that the surrounding surface and fuzzy numbers' intervals, belonging to the degree of comfort of the qualitative dimensions, were more in the control population as compared to the treatment ones, which indicates that the index of ergonomic interventions is positive in EC.

1. Introduction

The goal of interventions and the use of ergonomic science is to achieve logic and suitable relation between staff and work, where staff can have maximum productivity and production. Ergonomics studies staff psychology

and physiology in the working conditions, which is a complicated system among human, machine and environment (Shaliza et al., 2009). Many ergonomic analyses about human activities have roots in time and work studies that constitute the production engineering base. Productivity improvement is a simple way of encouraging management at the cost of programming and applying ergonomics interventions. This procedure can be more acceptable and impressive for the people having no ergonomic information, *i.e.* attention to productivity in ergonomic interventions provides a common language among stakeholders (Dempsey and Mathiassen, 2006). The demand of ergonomic interventions is more in the under-developed and industrially developing countries (IDCs). Scott (2008) has forecasted that clear differences become obvious when different communities have contact with each other or with the researches. The important role of organizational changes is to bring ergonomic concepts in organizations where the cultural changes need plenty of time to take place and the support of all senior managers is also needed for decreasing the ergonomics risk factors (Scott, 2008). Thus, it is necessary to research the possible ways and suitable conditions for moving from an ergonomic safety and hygiene pattern to an ergonomic business pattern without losing safety and health goals (Jan-Dul and Neumann, 2009).

Performance evaluation is one of the main duties of each organization and one of the aspects of performance management that has been executed via using financial indices (Wong-On-Wings et al., 2006). During the last two decades, the subjects of organization learning and creation of knowledge and innovation have been considered as the determining factors of competitive profit. This trend is increasing because of the expanding globalization, intensifying competition and progressing technology in the field of communication sciences and information (Lee et al., 2006; Andersen et al., 2006). In this respect, organizations should try to find comprehensive indices of performance, based on above subjects and having more emphasis on the soft performance indices (manpower) as their strengthening or weakening is not shown in financial balance-sheet (Andersen et al., 2006). One of the human performance indices that are not shown in balance-sheet is the effect of using ergonomics in organizations. The key factor of success for an organization is thought to be the physical and spiritual ability of its staff. Thus, power sustainability of an organization depends on the physical, psychological and spiritual health of their staff (Ozer-sari, 2009). So, various ergonomic evaluation methods have been used but the pre-existing internal criteria and rules of an organization measure the success or failure of an evaluation process. There are a limited number of research articles that study ergonomic evaluation methods (Berlin et al., 2009). Thus it is necessary to design a pattern that can intensify the effect of ergonomic interventions by increasing the accuracy and certainty of evaluation scores.

By considering the above stated principles, here we investigate and deliver a theoretical pattern for guiding total ergonomic interventions process (TEIP).During this project model, the performance evaluation and intervention process is based on five principles: management support, knowledge support, staff participation, performance evaluation with fuzzy logic approach, recognition and encouragement.

2. Materials and methods

2.1. Total ergonomic interventions in the framework of case study

An educational center (EC), having more than 250 instructors and employees and about 1000 students studying different courses including accounting and computer science, became interested in executing ergonomic evaluation and intervention for improving its performance. After undergoing various sessions of facilitating the method of “how to use ergonomics” at different departments, the authors became responsible for supervising and guiding the management of EC. The project was designed and executed under the title of “total ergonomic interventions” at two stages: micro- and macro-ergonomic interventions in the framework of Figure 1.

2.1.1. Macro ergonomic interventions

The first stage of the present study includes the application of macro-ergonomics. The main objective of the first stage was to improve different systems and processes for delivering services to students and other trainees including department stakeholders and EC staffs from macro ergonomics viewpoint. Systems and processes like: laboratories, participating students in delivering suggestions, evaluating processes for delivering services to students, increasing the quality of class rooms, encouraging staff, approaches for delivering recreational-welfare services to students and staff, optimizing service and production sections, human resource management and the process of optimizing manpower were considered in this study. Process of macro ergonomic interventions was

started by holding a 3-days workshop with the participation of 30 managers and staff members. A questionnaire was prepared and participants were wanted to share their views for EC. The present survey had main goals. The questionnaires were distributed and the participants were randomly divided into 6 different groups and their views were analyzed from the viewpoint of power, weaknesses, opportunities and threats. At the end of session, different group members demonstrated their results and after combining results of different groups, the final vision of EC was determined as follows: As "EC" is the biggest and the most important center of skilled higher education at regional and national level, its main responsibility is the production and processing of intended products in the frame of training pilots.

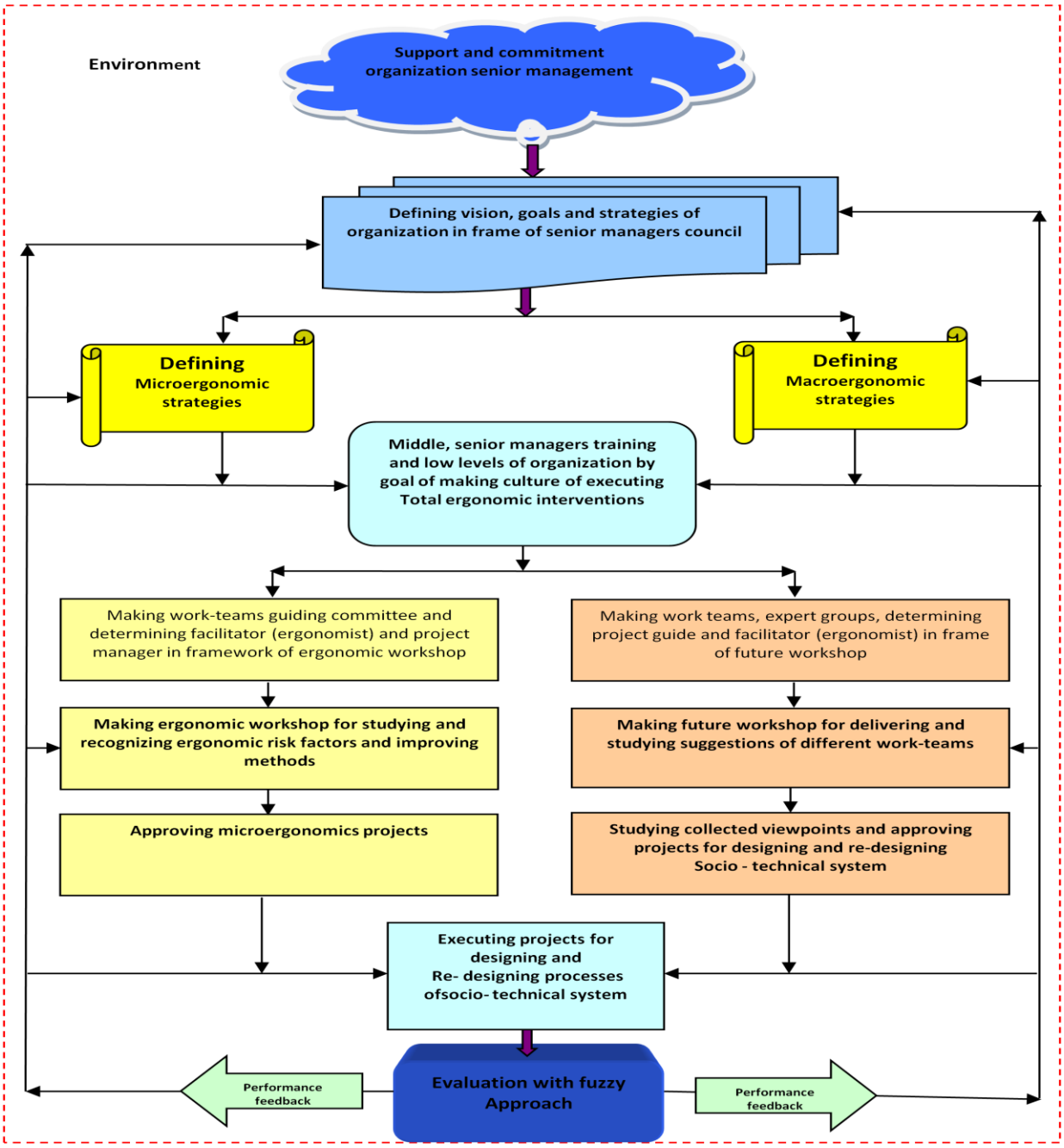

Fig. 1. Step by step stages executing total ergonomics evaluation and interventions model with fuzzy approach.

During the present study, staff members and students were used in EIP via future workshop. Future Workshop (FW) is a socio-pedagogic method for the identification of a common problem, development of a vision, ideas and action plan among a group of people concerned. This technique was proved to be successful in the Scandinavian countries and is being widely used as the participatory intervention method (Park and Han, 2004; Scott, 2009). Future Workshop is a well-structured process with five defined phases:

1- Preparation phase 2- Experience phase 3- Fantasy phase 4- Strategy phase. 5- Action phase/Follow up.

2.2. Micro ergonomic interventions

The delivered suggestions in macro ergonomic interventions for developing ergonomic culture and also continuous improvement of processes and decreasing dangers and ergonomic risk factors in EC sections was executed. This stage was started by a 2- day workshop like the first stage workshop, which was held out of the EC. A total of 35 members participated in this workshop. The goal of workshop was creating awareness among participants and developing recognition methods of ergonomic risk factors. The workshop started by introducing ergonomic inspection list for increasing productivity, safety and comfort (Helander, 1999). Project supervisor showed inspection list including 79 cases studied in 9 sections. Participants were divided into 7 groups in order to study the review factors in ergonomic inspection list (Table 1).

At the end of workshop, the members of missioner committee of preparing agendum or steering committee (SC) were chosen by project supervisor, coordinator and EC managing director. In this committee, 3 persons were chosen as the representatives of managing director, steering committee made a session and discussed about duties and activities of its members.

Table 1
Inspection list of ergonomic characteristics.

Row	Factors	Number
1	work, equipment and, lightness and clarity of tools	7
2	performing duties at vdt stations	6
3	requirements of seat workers	5
4	designing of the process and product	7
5	physical needs	14
6	mental needs	8
7	designing machines	12
8	working environment	7
9	safety issues	13

2.2.1. Performed actions at the micro ergonomic interventions stage

The activities of the micro ergonomic stage study are as follows:

1- Recognizing ergonomics risk factors, evaluating them and developing methods for solving problems (Helander, 1999).
2- Extracting Iranian static anthropometry and using it for optimizing work stations with computer, designing projects for theatre salon, conference salon, computer salon and etc; at the EC.
3- Determining the safety agendum of students and staff and executing insurance for students.
4- Holding continuous training courses for staff and scientific jury members and increasing their awareness about ergonomics.
5- Forecasting seasonal common sessions and discussing standards, safety and introducing successful patterns and researches, and encouraging staff about considering ergonomic suggestions.

2.3. Evaluation of total ergonomics interventions

The evaluation of this research took place in two ways:

a) Studying comparison performance before and after total ergonomic interventions in training and financial backgrounds (number of students present and articles delivered in scientific sessions, achieving scientific honors and etc.).
b) Studying MSDs via body mapping questionnaire (Tayari, 1997).

An encouraging was also designed to recognize the achievements of working groups and to encourage the staff for future cooperation and participation in work teams.

Executed projects were evaluated by SC based on systematic indices and the first evaluation immediately took place after using the project. The second evaluation would usually take place 3 months later and the evaluation one year after using project.

Project evaluation took place in the presence of working team coordinators. The total score that each executed project can get is 100, which is divided into 5 following factors:

1- Increasing income and profit (maximum 25 scores), based on the data and information collected by SC
2- Increasing number of students(maximum 20 scores)
3- Decreasing costs by saving human and non-human resources (maximum 20 scores)
4- Increasing safety and health (maximum 20 scores) based on registered data
5- Increasing work satisfaction (maximum 15 scores) based on the evaluation of staff opinions collected by SC

2.4. Determination of musculoskeletal disorders

Determination of MSDs was carried out with the help of ergonomics interventions. Effect, intensity and location of pain was also analyzed by using “body mapping questionnaire” (Tayarri, 1997), which can help seeking disorders being caused by the use of non-ergonomic chairs and their comparison with the ergonomic ones in five quality dimensions. A framework of 28 questions was prepared by dividing the body into 28 parts. The questionnaire also involved personal data of employees' including job, age, working hours (daily and weekly), height, weight, right or left handedness. The qualitative dimensions in the body mapping questionnaire were taken from “Servqual model”, used in the management of opinion classification and recognition (Van Lwaarden et al., 2003). During the present work, fuzzy triangular numbers were used according to Formula 1 (Zadeh et al. 1996), for analyzing and comparing the qualitative dimensions of sample and control populations.

$$\mu_A(x)=\begin{cases}\dfrac{x-a_1}{a_2-a_1} & a_1\le x\le a_2\\ \dfrac{x-a_3}{a_2-a_3} & a_2\le x\le a_3\\ 0 & o.w\end{cases} \qquad (1)$$

3. Results and discussion

This workshop started its work in the framework of above phases and continued for 4 months to study the problems and suggest solutions for solving them (Figure 2). Six months after the delivery program; many solutions were suggested by working teams and ergonomic group and delivered for getting the approval of managing director (MD). After necessary studies, some suggestions were approved by EC boss and were delivered for execution.

The three-years achievements of total ergonomic intervention (TEI) are described below as compared to the control year (start time of ergonomic interventions, the year 2007):

3.1. Comparison of the achievements before and after the application of total ergonomics

1- Saving 300.000.000 Rails monthly due to the optimization of man power.
2- A 280% increase in EC income in 2010 as compared to the base year.
3- A 617% increase in the approved credits as compared to base year.
4- A 30% increase in personnel's annual income as compared to base year.

5- A 15% annual saving in the costs of energy including gas oil and electricity (totally 75% increase as compared to base year)
6- A 600% increase in the number of students.
7- Preparing the University agendum and finding the co-operation of parents for the first time in country's Higher Education Institutions.
8- Optimization of man power by a 50% decrease in it.
9- Choosing one of the EC instructors as a distinguished researcher at the third festival of Researchers in Science and Technology in 2010.
10- Establishing the scientific society for student comprising 400 members.
11- Collaboration with Payame Noor University, Yazd, Iran for holding various training programs and projects.
12- Getting the permit for launching 18 new study courses of diploma and higher education.
13- A 500% increase in the publication of research article in scientific conferences and internal journals.
14- Launching internet and computer based official systems, which has reduced the use of paper.
15- Launching an up-to-date EC web site: http://yazd.itvhe.ac.ir.
16- Establishing theatre salon by considering ergonomic principles by extracting and using Iranian anthropometry, which has taken place in ergonomic interventions).
17- Establishing and using multi-purpose conference salon, equipped with computer and wireless internet system by considering ergonomic principles.
18- Getting EC preferred title from a total of 220 Educational Centers of Applied Sciences at the third Festival of National Applied Science Universities in 2008.

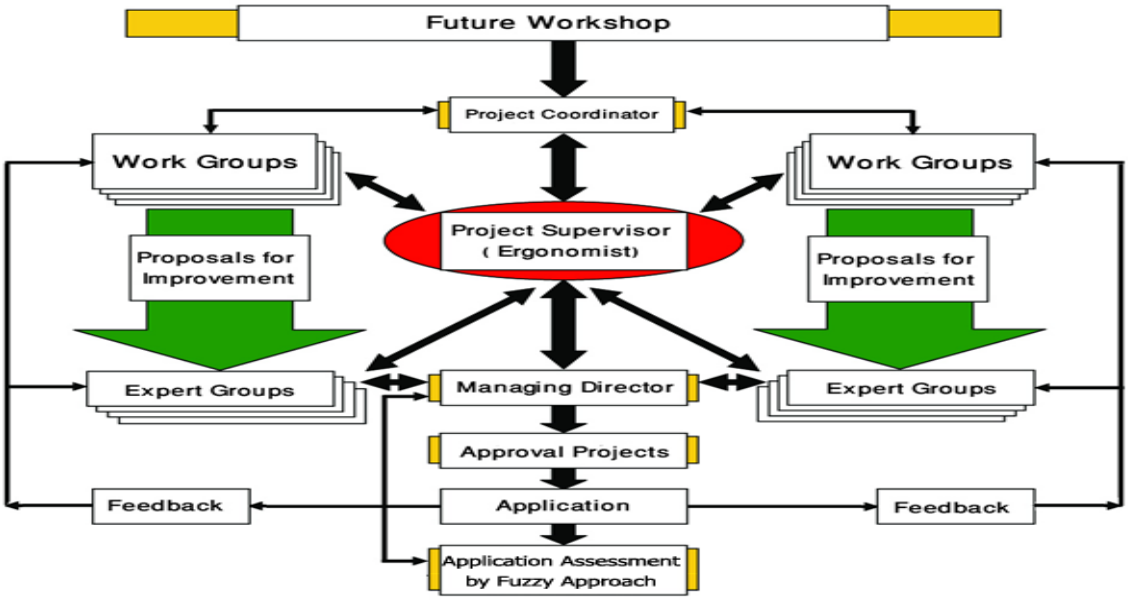

Fig. 2. Proposed Model for working within of project of total ergonomic interventions

3.2. Comparison of the opinions from control and sample population with fuzzy approach

For comparing these two populations, in this study, ranking triangular fuzzy numbers (surrounded level) and triangular fuzzy number interval were used. For getting the opinions of chair stakeholders, they were required to investigate the effect of chairs and the type of disorder caused after use. The effect of disorder was seen at each of the body parts in qualitative 5-dimension (fuzzy choices: Without discomfort, little discomfort, partial discomfort, very uncomfortable, intolerable pain) in "body mapping 28-part questionnaire" by writing 1-5 (Figure 3).

From 77 questionnaires distributed among the members of control population, 65 were completed and handed-over. While, from 133 distributed questionnaires among sample population, 107 were completed. For

summarizing and analyzing the statistical data comparison, fuzzy numbers are used according to fuzzy choices stated in Table 2 and Figure 4 (Herrwva and Herreva-viedma, 2000; Zadeh, 1975, 2008).

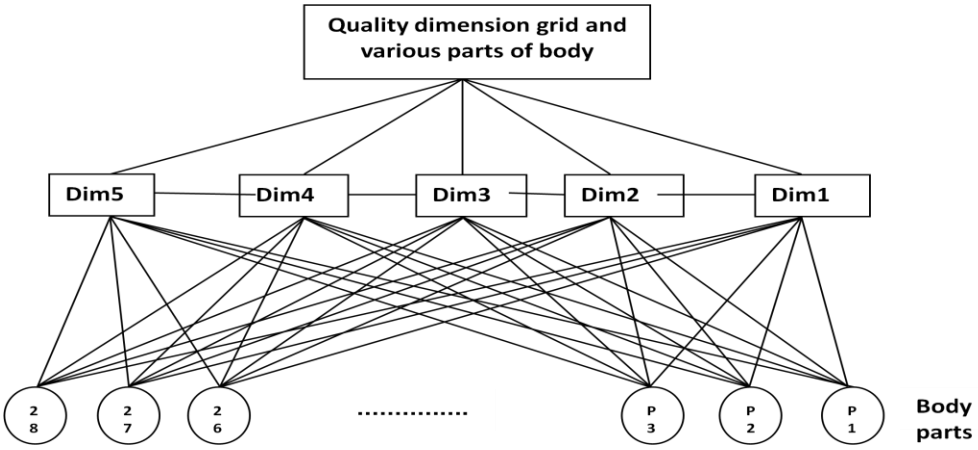

Fig. 3. Grid diagram of quality dimensions and various parts of body.

Table 2
Presentation of fuzzy numbers and options applied in analyzing the statistical data of qualitative dimensions.

Sign	Weight choice (Fuzzy number)	Linguistic phrase	Linguistic phrase
P	(0.75,1,1)	Extraordinary important	Intolerable pain
L	(0.5,0.75,1)	Very important	Very uncomfortable
M	(0.25,0.5,0.75)	Important	Partial Discomfort
H	(0,0.25,0.5)	A little important	Little Discomfort
V	(0,0,0.25)	Not important	Without Discomfort

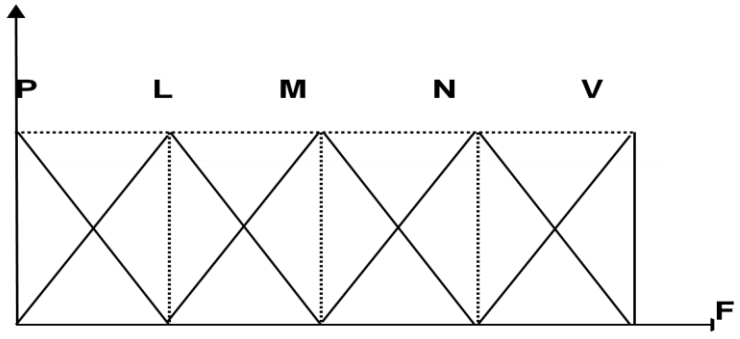

Fig. 4. Presentation of fuzzy options of qualitative dimensions applied in fuzzy analysis.

After summarizing the data of questionnaire, fuzzy number average containing the weight was computed from getting opinions from control and sample population (Table 3).

Table 3
Fuzzy number average having weight calculated by collecting the community opinions with the help of the qualitative dimensions from sample and control community body map questionnaire.

After ergonomic intervention (sample community)				Before ergonomic intervention (control community)				Qualitative dimensions
	W_i				W_i			
(0 , 0 , 6.2)	24.85	107	2658	(0 , 50 ,)	20	65	1304	**Without Discomfort** Fuzzy number (0 , 0 , 0.25)
(0 , 0.56 , 1.23)	2.262	107	242	(0 , 1.02 , 2.55)	4.08	65	265	**Little Discomfort** Fuzzy number (0 , 0.25 , 0.5)
(0.34 , 0.68 , 1)	1.35	107	144	(0.73 , 1.45 , 2.2)	2.91	65	189	**Partial Discomfort** Fuzzy number (0.25 , 0.5 ,0.75)
(0.2 , 0.3 , 0.4)	0.4	107	43	(0.76 , 1.14 , 1.5)	1.523	65	99	**Very Uncomfortable** Fuzzy number (0.5 , 0.75 , 1)
(0.098 , 0.13 , 0.13)	0.131	107	14	(0.37 , 0.49 , 0.49)	0.492	65	32	**Intolerable pain** Fuzzy number (0.75 , 1 , 1)

N_i= Frequency of response to qualitative dimension i
n_i=Community members undertaking questionnaire with performed ergonomic interventions and the control community (sample numbers),
W_i= Frequency of response to qualitative dimension i for each community member (Ni/n_i)
WF_i = Fuzzy numbers having weight.

3.2.1. Ranking fuzzy numbers of control and sample population opinions

Number has basic role in mathematics, while the fuzzy number has basic role in fuzzy mathematics. One of the most important topics in the practical use of fuzzy numbers is regulating fuzzy numbers (or fuzzy bases). Different methods have been developed for determining the fuzzy number order. During the present study, surrounded level was used for regulating qualitative dimensions related to sample community, which were declared based on triangular fuzzy numbers. The point to be noted here is that the computation of surrounded level can either be a positive, negative or a zero numeral.

For ranking triangular fuzzy numbers A_i= (L_i,M_i,U_i), three following criteria have been taken into account (Zimmermann, H.J., 1996):

1) Computation of surrounded level (Formula 2)

$$S(_i) = \frac{Li + 2Mi + Ui}{4} \quad i = 1, 2, 3 \ldots n \qquad (2)$$

Where, L_i= the minimum,M_i= the most possible,U_i= the maximum amount of intended qualitative dimension.

2) Mode (A_i) = M_i

3) Range of fuzzy number.

The above three criteria are used in combination or after each other, *i.e.* first criterion is used after the computation, second criterion in equal conditions and third criterion in repetitive equal conditions. According to Table 4, the results of ranking fuzzy numbers have shown that $SA_1 < SB_1$, $SA_2 > SB_2$, $SA_3 > SB_3$, $SA_4 > SB_4$, $SA_5 > SB_5$. As a result, MSDs (qualitative dimensions of declared disorders by persons) have become less after ergonomic interventions because surrounded level, belonging to the qualitative dimension “without discomfort” in sample population, is more than that of control population. While, the surrounded levels of qualitative dimensions of little discomfort, partial discomfort, very uncomfortable, and intolerable pain, belonging to the sample population, is less than that of control population.

Table 4
Surrounded levels and fuzzy number interval of control and sample population studied with total ergonomic interventions.

Qualitative dimensions	Control population (SA_i)	Sample population (SB_i)	Surrounded level interval $S(A_i\text{-}SB_i)$	Analysis results analysis
Without Discomfort	1.25	1.55	-0.3	$SA_1 < SB_1$
Little Discomfort	1.02	0.57	0.45	$SA_2 > SB_2$
Partial Discomfort	1.43	0.66	0.77	$SA_3 > SB_3$
Very Uncomfortable	1.14	0.3	0.84	$SA_4 > SB_4$
Intolerable pain	0.46	0.122	0.34	$SA_5 > SB_5$
Total	5.3	3.2	2.1	$\sum SA_i > \sum SB_i$

3.2.2. Computing interval of fuzzy numbers of sample and control population

Interval of two triangular fuzzy numbers of $\widetilde{N}_i(b_1,b_2,b_3)$ and $\widetilde{N}_i(a_1,a_2,a_3)$ can be computed as follows:

$$S(\tilde{N}_i,\tilde{N}_j)=\frac{1}{2}[S_L(\tilde{N}_i,\tilde{N}_j)+S_R(\tilde{N}_i,\tilde{N}_j)]$$

In which, $S_L\left(\tilde{N}_i,\tilde{N}_j\right)$ and $S_R\left(\tilde{N}_i,\tilde{N}_j\right)$ are equal:

$$S_L\left(\tilde{N}_i,\tilde{N}_j\right)=S_L\left(\tilde{N}_i,0\right)-S_L\left(\tilde{N}_j,0\right)=\frac{a_1+a_2}{2}-\frac{b_1+b_2}{2}$$

$$S_R\left(\tilde{N}_i,\tilde{N}_j\right)=S_R\left(\tilde{N}_i,0\right)-S_R\left(\tilde{N}_j,0\right)=\frac{a_2+a_3}{2}-\frac{b_2+b_3}{2}$$

Then, the interval of two fuzzy numbers $\widetilde{N_i},\widetilde{N_j}$ will be equal to:

$$S\left(\tilde{N}_i,\tilde{N}_j\right)=\frac{1}{2}\left[\left(\frac{a_1+a_2}{2}-\frac{b_1+b_2}{2}\right)+\left(\frac{a_2+a_3}{2}-\frac{b_2+b_3}{2}\right)\right]$$

$$=\frac{1}{2}\left[\frac{a_1+2a_2+a_3}{2}-\frac{b_1+2b_2+b_3}{2}\right]$$

$$=\frac{(a_1+2a_2+a_3)-(b_1+2b_2+b)}{4}$$

$S\left(\tilde{N}_i,\tilde{N}_j\right)$ is the algebraic distance of $\tilde{N}_i$ from $\tilde{N}_j$ ($\tilde{N}_i$- $\tilde{N}_j$), which can be positive, negative or zero (Zadeh, 1987).

By using the following formulas, the interval of fuzzy numbers has been computed for the present study, as shown in Table 5.

$$S\left(\tilde{pp}_3,\tilde{sp}_3\right)=\frac{[0.73+2(1.4)+2.2]-[0.33+2(0.66)+1]}{4}=0.77$$

Table 5
Analysis offuzzy number intervals from sample and control population.

Row	Fuzzy numbers having weight (control population) PP_i	Fuzzy numbers having weight (sample population) SP_i	Fuzzy numbers interval $S(PP_iSP_i)$	Interval analysis
1	(0,0,5)	(0,0,6.2)	-0.3	Since qualitative dimension interval "without discomfort is negative and the others intervals are positive, ergonomic interventions has had positive effect in decreasing disorders.
2	(0,1.02,2.04)	(0,0.57,1.15)	0.45	
3	(0.73,1.4,2.2)	(0.33,0.66,1)	0.77	
4	(0.76,1.14,1.52)	(0.2,0.3,0.4)	0.84	
5	(0.37,0.49,0.49)	(0.098,0.13,0.13)	0.35	
Sum	(1.86,4.05,11.25)	(0.53,1.66,8.88)	-	

4. Conclusion

The results of present study involve the successful participation of staff, which is an attractive issue in ergonomics. Imposing opinions and not paying attention to staffs' ideas can make the program fail even in the beginning. Increasing general knowledge and occupants potential abilities on one side and launching the ergonomic programs on the other side can be helpful in solving the workplace problems including the ergonomic issues. During the present study, the efficiency of all units was improved due to team work, execution of the ergonomic factors at workplace, low-cost solutions and even the help of saved resources for solving small and intermediate problems, which includes improvements such as; preparing ergonomic chairs, suitable tables by considering the anthropometry of stakeholders and the preparation of suitable places for keeping paper and other recyclable products, bright rooms and corridors. The results of ergonomics interventions in this research have shown a decrease in MSDs and an increase in productivity in different sections of EC. On the other hand, by making culture of using ergonomic knowledge, a person can take help of suitable support tools and perform low cost ergonomic improvements that can be effective in improving the working condition of any institute. As a conclusion, the total ergonomics intervention processes can help an organization in achieving the direct and indirect profits.

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