

An Ergonomic Evaluation and Intervention Model: Macro ergonomic approach

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Abstract—The nature of ergonomics performs a unique role in protecting human health and preventing health risks. It is clear that improvements in productivity indices in the systems can be seen, resulting in better work conditions for people employed in production and services systems. Investigative results reveal that theoretical and applicable discussions about ergonomic science have not been considered seriously. In this research, a theoretical model has been developed and operated in an educational organization (EO) in order to lead and guide the "Ergonomics Interventions Process (EIP)" and to evaluate it. Therefore, EIP begins with macro ergonomic intervention and then the necessary planning is done and applied in the second stage simultaneously for micro ergonomic interventions. In this study, the results of "Total Ergonomics" (Micro and Macro ergonomics) intervention evaluations show that positive effects of applying this knowledge can be seen in increased productivity and reduced musculoskeletal disorder (MSDs). A performance comparison with the base year indicates lower costs, increased revenue and more work accomplished with a smaller work force. Data analysis of "body mapping questionnaire" showed a significant difference in confidence of ninety-nine percent between the sample and control population and a reduction in the number of musculoskeletal disorders. These indices indicate the positive effect of intervention ergonomics.

Index Terms— Macro Ergonomics, Micro Ergonomics, Developing Countries, Musculoskeletal disorders, Productivity, Evaluation

1 INTRODUCTION

THE goal of intervention and the application of ergonomic knowledge is to achieve a logical and suitable relation between staff, machines and the organization of work. In these conditions staff can achieve maximum productivity. Ergonomics studies staff psychology and physiology at work which is a complicated system of humans, machines and work [1]. Most ergonomic analysis of human activities originates from work and time [2] which establishes the basis of production engineering; as a result it is natural to analyze and consider ergonomics and productivity together. Improving productivity is a simple method of encouraging management to set aside a budget to cover the costs of programming and applying ergonomics intervention. This method can be acceptable and more impressive for persons without ergonomic information [3]. The important point in organizational change is that ergonomic concepts should be as a culture in organizations and this culture change needs a long time and the support of upper management due to decreasing ergonomic risk factors. Upper management should have a close relationship with the organizations work force in order to create a belief in ergonomic concepts and to ensure that the system enjoys continuous improvement [4]. Thus it is necessary to perform research work to use and study the effects of ergonomics interventions to achieve suitable conditions in production service systems, especially in industrially developing countries (IDCs) [5]. To achieve this

goal, it is necessary to design a pattern to be used in programming, application and evaluation of ergonomics interventions.

2 DEFINING RESEARCH SUBJECT

Performance evaluation is a major responsibility of all organizations and one aspect of performance management is the application of financial indices [6]. In last two decades, subjects like organizational learning, knowledge creation and innovation capacity have been considered as determining factors of competitive advantage and this concentration has been due to globalization, intense technological competition and progress in the fields of information and communications [7]. Organizations should try to find comprehensive performance evaluation indices based on the above subjects with more emphasis on soft performance indices (human), as human weaknesses are not shown in balance sheets [8]. One of the soft performance indices not shown in a balance sheet is the effect of applying ergonomics in organizations. As in the present era, human resources are a key factor for an organization's success. An organization's strength is its staff and the sustainability of an organization depends on the physical, psychological and spiritual health of the staff [9]. Many ergonomic evaluation methods have been applied as goals of work analysis but industrial companies use related and internal methods or prepared measures at a national level like refusal or acceptance measures. As a result, very few research articles are based on ergonomic evaluation methods [10]. Thus designing a pattern is necessary in order to apply and study the effects of total ergonomics intervention (micro and macro ergonomics).

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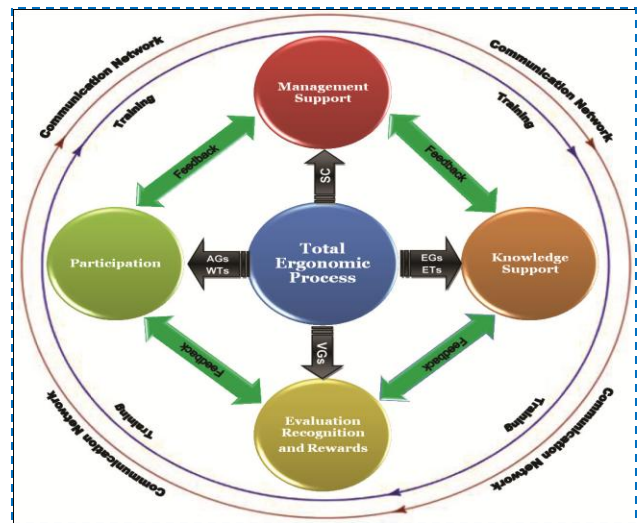
3 REVIEWING RESEARCH LITERATURE

By developing and using ergonomics knowledge, research has also moved in coordination with it. Some research opposes work-related musculoskeletal disorders (MSDs) which have caused recent advances in the effective research of ergonomics interventions for different reasons. In spite of many studies in recent decades in the field of ergonomics, many organizational factors cause skeletal disorders and costly ergonomic diseases [11], which shows that ergonomic changes are still not very effective [12]. Since applied ergonomic principles have been recognized as a saving method for decreasing MSDs [13], it is necessary to perform research to recognize ergonomic risk factors and to develop approaches to solve problems at work, thereby increasing productivity. There have been many obstacles in studying the effects of ergonomic intervention for prohibiting MSDs [14]. Globalization and intensive competitiveness can increase security risks [15]. On the other hand, ergonomic studies show that weakly designed systems neglect ergonomic principles irritate staff. Not considering ergonomic principles can provide emotional and physical stress and less productive work. Effective execution of ergonomic programs can increase ergonomic awareness. The research results show that distributing ergonomic knowledge among staff leads to better execution of production service programs. NIOSH in Malaysia has shown that virtual display terminal staffs are faced with psychic diseases including stress, tiredness, anger and depression, and staff productivity has decreased. Applying ergonomic knowledge at work can decrease psychic diseases [16]. In spite of many ergonomic studies, many factors cause MSDs and costly ergonomic diseases which show ergonomic changes are still not very effective. Thus all ergonomics researchers should coordinate the various fields of ergonomic factors related to work [5]. Until now, many ergonomic evaluation and applied methods have been developed and validated ergonomics evaluation methods aimed at workplace analysis (such as RULA [17], Strain Index [18], REBA [19], the Cube model [20] etc.). Studies of their application in industrial settings have been performed [21, 22, 23], but the reality is that industrial corporations often develop their own internal methods for evaluation, or use a national provision as pass-fail criteria. Consequently, research articles that address corporate internal or national standard ergonomics evaluation procedures are few and far between [10]. Therefore evaluation and necessary research should take place for omitting problems and developing these methods. By considering basic points in ergonomic research and issues of designing and organization management and its relation with macro and micro-ergonomics and other issues, the following principles in the subject model of this research are considered: 1) Intended model framework is considered in manner and structure, thus by using macro-ergonomics concepts model, structure framework is designed and by applying micro ergonomic concepts we consider model manner framework. 2) in performance evaluation models, relations are one-way but in model of this research, relations which are up to down, down to up, and from middle-out will be considered. 3) Intended

pattern determines recognition method of risk factors and ergonomics indices. 4) Supporting knowledge, management, and staff participation; Recognition and reward and Information and communications network.

4 SUGGESTED MODEL FOR ERGONOMIC EVALUATION AND INTERVENTION PROCESSES

Ergonomic interventions should be considered as an improvement process in all aspects. Since changes are continuously related to all organizational aspects, it is better to provide an intervention process that can improve all kinds of problems due to changes in technology, organization and environmental factors (internal and external). By considering the principle and subjects mentioned above, a theory pattern is delivered for guiding ergonomic interventions processes and is executed in a training set. In this model, performance evaluation and intervention process is based on four principles: management support and logistics, knowledge support, evaluation and staff participation, encouraging and defining. An intervention process by training managers, staff and members of work groups is established and a feedback system is provided and designed with the help of these four principles. For the successful continuity of effective evaluation and intervention process, designing and developing a suitable communications network system from up to down (developing a strategic programming suitable method) and down to up (applying a participatory ergonomics) and from middle-out to up and down (concentrating on activities) are considered



(figure. 1).

Figure.1: Total ergonomics evaluation and intervention process model

Training is an important item of understandable and systematic findings which causes access to and application of knowledge in an organization. Ergonomic interventions start with training and necessary changes are performed by awareness. Training and the know-how to transfer ergonomic

knowledge is a continuous process by which ergonomic knowledge intervention conditions are prepared in the intended system, i.e. a project expert or manager, as an ergonomic specialist, transfers his experience to staff and employs trainees (participants at work) to launch ergonomics in a suitable fashion [24]. The ergonomic specialist's role for guiding and launching ergonomics and exerting necessary changes has been explained in the process of staff participation in ergonomic designs. This complicated role in the launching process can be considered by people in and out of the organization. It is necessary to mention that an ergonomic evaluation and intervention process should be regulated based on confidence, impressive relation, available realities and adjustment to the needs of the overall ergonomic design. Cultural realities are performed as programs by these interventions on them. Staff and lectures process the application of ergonomic knowledge in the framework of different organized work teams. They are trained in work groups how to participate and design the systematic framework, how to make documentation and follow-up activities. They are also trained in ergonomic principles, to recognize problems related to ergonomic knowledge, to deliver services or system production, problem analysis, delivering possible suggestions for solving problems and to improve execution through lowering costs. It is suggested to participants as project group members are chosen with different skills, i.e. they can work effectively with group members with different backgrounds, ideas and specializations. Each one of them should have the ability to limit his personal tendencies to achieve the goal that has been established for the group [25] by considering ergonomic intervention needs to participate in all aspects at different levels of organization for recognizing it and impressive analysis of solving ergonomic problems [26]. Besides supportive management and a culture of accepting opinions in a democratic environment, work group training is another necessary feature for ergonomic evaluation and intervention success. We should pay attention to the fact that improving a system is not a short-term process but a long-term process that needs the continuous support of management for activities and ergonomic designs. By designing and applying a feedback system with the participation of work groups, management can make them more responsible towards the organization and its goals. A feedback system is necessary for an organization's success and should be acceptable to all persons working in the project. Firstly, this feedback system should provide information for training programs in order to determine the necessary and correct activities. Secondly, empower positive results and profits related to learning skills at work. The feedback system should be designed by participating staff and should consider time and kind of feedback information required by different groups. The management system should encourage work teams members to be active and to continuously participate. Thus, for successful and continuous intervention process, an invention evaluation system should be considered by encouraging, determining and developing the frame of communication and information network system. The

ergonomic interventions process should be evaluated at regular time intervals by an evaluator group certified by the organization's managers to make sure that intervention progress is being made. The management and evaluation group should develop an evaluation system and test it before establishing a final system which is to be accepted by all project members. Based on evaluation results of ergonomics interventions process, project participants who get considerable results and are impressive in achieving goals should be encouraged to develop cooperation among organization members. Usually activities cause increased production, work quality enhancement, health improvement, safety and satisfaction of staff and work safety. The social aspects of an organization should be recognized and encouraged. The timing of these evaluations and the delivery of encouragement are also important and should not last very much after evaluation process. Studying evaluation system results, recognition and encouragement should be made by all participating project members and managers. Thus providing a relation system from up to down and from down to up and from middle-out to up and down is necessary to ensure all participants in the execution of ergonomic projects have all the necessary information to be active in the ergonomic evaluation and intervention process. For collecting ergonomic information, organization's higher managers information is used because the support of upper management of an organization having close relations with low level staff can play a considerable role in improving an organization's production process. The important point in organizational changes is that ergonomic concepts should be considered as culture in organizations [27] and this culture change needs too much time and support from all higher managers of an organization. In order to decrease ergonomic risk factors, there should be a close relationship between upper management and the low level work force of an organization because creating ergonomic concepts requires the opinion of all members of an organization and all change processes cover systems that need regular improvement. To achieve this goal, an integrated systemic model is suggested for total ergonomic interventions to be executed step by step.

5 ERGONOMICS INTERVENTIONS IN FRAMEWORK OF CASE STUDY

A training center (which will be called EO from now on) was interested in executing programs of ergonomic evaluation and interventions to improve performance. More than 250 lecturers and employees as well as approximately 2000 students in different related courses such as accounting and computer science participated. After several sessions to facilitate an appropriate method of ergonomics application in different parts, the author assumed responsibility for managing and supervising the project and for guiding all persons during the process. The project, entitled "Total Ergonomics Interventions" was designed and executed in two stages: micro and macro ergonomic interventions.

5.1 Macro ergonomic interventions

The first stage of the project included the process of applying macro ergonomics. The major goal at the first stage included stakeholders and staff of EO center from the viewpoint of macro ergonomics. Systems and processes such as labs and student participation were considered in this study including the delivery of suggestions, the evaluation of the process of delivering services to students, increasing the quality of holding classes, encouraging staff, solutions for delivering recreational welfare services, optimizing service and production sections, human resources management and the process of optimizing human force. The process of macro ergonomic interventions began with a 3-day workshop attended by 30 managers and staff. This workshop was held to find a common viewpoint to EO and to regulate different goals towards the achievement of a special vision of EO. A questionnaire was prepared and participants were asked to formulate an EO viewpoint and to develop at least 3 major goals to achieve an understandable vision. The questionnaires were distributed, completed and collected. Then by summarizing subjects of the workshop, an EO vision was determined which included the two following items:

- 1- EO is the biggest and the most important higher education center at regional and national levels.
 - 2- EO is a pioneer in the production and processing of products in the frame of training pilots.
- The delivered goals for achieving vision were then summarized and approved (Table.1).

TABLE 1: THE MOST IMPORTANT GOALS FOR ACHIEVING VISION

No.	Goals Titles
1	Recognizing new technologies in related sections and transferring these goals to students, stakeholders and official experts in section.
2	Improving the quality of welfare cultural programs for students and staff by improving methods and by acquiring new investments.
3	Human resource management (optimizing human force) by applying, maintaining, training and encouraging staff.
4	Providing the necessary background to deliver innovation in performance and training programs.
5	Developing training courses and admitting more students.
6	Cooperation with international and large training centers.

5.1.1 Manner of students and staff participation in macro ergonomic interventions

For impressive use of staff and students in EIP via future workshop was used. Future Workshop (FW) is a socio-pedagogic method for identification of a common problem, development of a vision, ideas and action plan among a group of concerned people. The method was first introduced by the scientist "Robert Jungk" from Germany (1984). Later on it was spread successfully to the Scandinavian Countries and is now widely used as a participatory intervention method [27]. 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. This workshop began working on the framework of the above phases and after studying the problems for 4 months suggested solutions to solve them. The most suggested approaches were delivered in order to attract the participation of people and to use their potential capacities to solve problems. Executive policies and programs delivered in future workshop (Table 2).

TABLE 2: SUMMARIZING DELIVERED EXECUTIVE POLICIES AND PROGRAMS AT FUTURE WORKSHOP

No.	Polices and Program Titles
1	-Organizing an official place with the goal of decreasing musculoskeletal and physic stress via: -Extracting Iranian anthropometry and using it to design a theater salon, conference salon, computer salon, classes etc. -Recognizing ergonomic risk factors, evaluating them and determining solutions to problems. -Programming and executing ergonomic training courses for scientific jury members and staff.
2	Encouraging staff and students to develop a cooperative culture and to remember EO.
3	Providing the necessary background to students to execute the applied research needed for each related section.
4	Empowering applied scientific relations with related sections via the opening of a relation office with industry at EO.
5	Programming research scientific relations among EO and applied scientific centers in and out of the country.
6	Programming for using applied research findings for student's educational programming.
7	Approving and establishing a conference salon for using different training by considering ergonomic principles.
8	Students' skill based activities towards defining income generating projects and designs.
9	Equipping labs with modern tools and establishing specialized labs.
10	Programming for exchanging students with other countries.

5.2 Micro ergonomic interventions

The suggestions delivered at the macro ergonomic interventions stage were executed at EO subsections for extending and developing ergonomic culture and also continuous improvement of processes and decreasing the ergonomic risk factors. The EO higher management agreed with the suggestion of executing a micro ergonomic intervention process to improve the work situation and to increase productivity as the second stage of ergonomic interventions process. This stage began with a 2-day workshop. Like the first stage, 35 staff members participated and were responsible for a section of the workshop. The goal of the workshop was to increase ergonomic awareness among participants and to teach recognition methods of ergonomic risk factors related to place and work situation improvement. The workshop began by introducing an ergonomic inspection list designed to increase productivity, safety and comfort

ability [28].The project supervisor showed an ergonomic inspection list which included 79 ergonomic inspection cases, and explained to the participants how to use it at their work. Participants were divided into 7 different groups and each group studied all 79 factors and tried to understand why and how to study each of these factors, and to adjust and explain their work in relation to their own work experience. They were also asked to write down their experiences about each of studied points and if they have any executive suggestion for improving their work place by using these factors. If they answered yes, they prioritized these activities. Members of different groups then gathered and showed each other the acquired result summary and discussed decisions to suggest activities and their priorities. They also suggested solutions for solving problems. After holding the workshop, committee members were chosen to prepare a work program or steering committee by the project supervisor, project coordinator and EO higher manager. In this committee, 3 persons were chosen as EO higher manager and then the steering committee held a session and discussed and approved the work team as well as steering committee duties and activities.

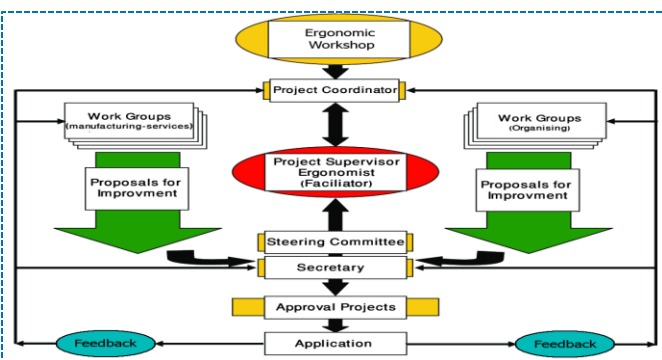
5.2.1 Accomplished activities at micro ergonomic interventions stage

TABLE 3: EXECUTED PROJECTS AND DESIGNS AT MICRO ERGONOMIC STAGE

no.	projects and designs Titles
1	Designing and executing necessary projects to facilitate training execution such as teaching classes at supported forms.
2	Enriching staff work and basis of EO training and executive different sections by combining parallel and similar works.
3	Extracting Iranian static anthropometry and using it for optimizing and designing approved projects.
4	Recognizing ergonomic risk factors, evaluating them and choosing solutions to solve ergonomic problems.
5	Holding ergonomic training courses for scientific jury members and staff once every three months.
6	Introducing successful patterns and research and encouraging staff to consider ergonomic suggestions.
7	Preparing a student and staff safety agendum and executing student insurance.

The most important actions taken at this stage by the work team, the action group for executing defined projects and the ergonomics group and steering committee (framework shown in Figure.3) are mentioned in table 3.

Figure 3. Activity Diagram of Ergonomics Workshop



6 EVALUATING TOTAL ERGONOMIC INTERVENTIONS

Until now there have been no considerable results for recognizing ergonomic problems and solving them such as increasing productivity and decreasing MSDs. The performed Evaluations and results of total ergonomic intervention are delivered in a continuous manner. The evaluation in this research is done in two ways:

- 1- Studying MSDs via body mapping questionnaire e [29].
- 2- Studying a comparison of performance before and after ergonomic inventions in different training and financial backgrounds (number of students, number of delivered articles in scientific sessions, acquiring research scientific honors etc.).

7 RESULTS AND DISCUSSION

The most important three year achievement due to total ergonomic intervention (TEI) compared to base year (starting time of ergonomic interventions, 2008) are:

7-1 Comparison of achievements before and after Total ergonomic interventions

The most important three year achievements due to total ergonomic interventions have been summarized in comparison to the base year in table 4.

TABLE 4: COMPARISON OF ACHIEVEMENTS BEFORE AND AFTER TOTAL ERGONOMIC INTERVENTIONS

no.	Achievement Titles
1	Acquiring EO preferred title among 220 state applied scientific training centers at the third festival of applied scientific comprehensive universities in the country.
2	500% increase of delivering articles in scientific assemblies and foreign and internal scientific research publications.
3	Getting permits to launch 18 new courses of study at higher-diploma and expertise as compared to the base year.
4	Establishing a theater salon by considering ergonomic principles and using Iranian anthropometry.
5	Establishing and using multi-apply conference salon by considering ergonomic principles.
6	Optimizing human force due to 50% decrease in human force.
7	15% annual energy cost savings including gas, oil and electricity.
8	Executing a paperless system in official writings and data packets.
9	280% EO increase in income in1388 as compared to the base year.
10	30% annual increase in personnel income as compared to the base year.
11	Acquiring a distinguished researcher title in related sections.
12	600% increase in number of students.

7.2 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" which can help seek disorders 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 qualitative dimensions in the body mapping questionnaire were taken from "Servqual model", used in the management of opinion classification and recognition [30].

To determine the opinion of chairs, stakeholders spent two hours using the chairs. They were asked to determine their disorder at each body part in 5 qualitative dimensions (No Discomfort, Less Discomfort, Partial Discomfort, Much Discomfort, Intolerable pain) in a 28 part "body mapping questionnaire" by expressing their discomfort on a scale of 1-5. From 77 questionnaires distributed among the control population, 65 questionnaires were completed and returned and from 133 distributed questionnaires among the sample population, 107 questionnaires were completed and returned. After summarizing the questionnaire data, the aggregated results of body mapping questionnaires and the relevant calculations are shown in table 5.

TABLE 5: NUMBERS CALCULATED BY COLLECTING THE COMMUNITY OPINIONS WITH THE HELP OF SAMPLE AND CONTROL COMMUNITY BODY MAP QUESTIONNAIRE QUALITATIVE DIMENSIONS

After ergonomic intervention (sample)			Before ergonomic intervention (control)			Qualitative dimensions
F_i	n_i	N_i	F_i	n_i	N_i	
24.85	107	2658	20	65	1304	No Discomfort
2.262	107	242	4.08	65	265	Less Discomfort
1.35	107	144	2.91	65	189	Partial Discomfort
0.4	107	43	1.523	65	99	Much Discomfort
0.131	107	14	0.492	65	32	Intolerable pain

N_i = Response frequency to qualitative dimension i

n_i = Community members undertaking questionnaire with performed ergonomic interventions and the control community (sample numbers)

F_i = Response frequency to qualitative dimension

TABLE 6: STATISTICAL ANALYSIS RESULTS IN TABLE FORMAT AGREED

Observed Values	Expected values	χ^2 . $\alpha=0.01, df=3$	χ^2 Calculated
2658	2464.045	(11.34)	(214.6514)
247	318.4228		
142	204.6115		
43	88.31256		
14	28.60829		
265	193.5772		
187	124.3885		
99	53.68744		
32	17.39171		

For significant analysis of the differences between the frequencies of qualitative dimensions of control and sample populations, a Chi square test in the form of a contingency table is used [31]. According to test results (Table 6), there is a significant difference of 99% between control and sample population (Null hypothesis against Alternative hypothesis is rejected). This result demonstrates the positive effects of ergonomic interventions.

8 DEDUCTION

In short, we can say that ergonomic intervention processes delivery many benefits besides the achievements delivered in Section (7) for EO and staff. These benefits can be divided into two categories as follows:

The direct benefit of all units was improved due to work team activities and executing ergonomic factors at work besides those achievements delivered in this project. Work teams suggested low-cost or no cost solutions for small and average problems at work which were mainly executed with the help of saved resources. On the other hand, by creating a culture of applying ergonomics, a person can perform impressive low-cost ergonomic improvements on equipment, and improve work methods with the help of suitable supporting tools.

The indirect profits of ergonomic interventions process provided for an active and continuously advancing environment in EO. The staffs are now more aware in their work place and cooperate to find solutions to solve available problems. Based on the opinion and belief of EO management, staff motivation to participate and innovate to solve problems has increased as compared to the base year and they have become more responsible for their work and are more creative in delivering new ideas. Staffs participate and help more during work and problem solving.

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