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The Impact of Participatory Ergonomics on Working Conditions, Quality, and Productivity

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A participatory ergonomics model was designed for improving working conditions, quality, and productivity in a medium-sized manufacturing enterprise by making use of a Supportive Expert Team (SET).

In order to implement the model, a team-based structure consisting of a Steering Committee (SC) and 2 Action Groups (AGs) was designed and a 5-phase methodology followed. To validate the model, a similar factory was selected as control.

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Performance of the model was successful throughout the project. AGs under the supervision of the SC and the support of the SET designed and implemented several ergonomics solutions using local resources.

Our findings showed that, in comparison with the control factory, application of such a model could be considered as a provider of a more humanized work environment as well as a more efficient and cost-effective approach.

participatory ergonomics quality productivity team working intervention

1. INTRODUCTION

Participatory ergonomics (PE) emphasizes utilization of employees' potential for conducting ergonomic improvements at work. The approaches and methods of PE differ from traditional ergonomics, which relies mostly on ergonomics experts as change agents. PE is one of several macroergonomics strategies for implementing ergonomics. The fact that PE is anchored in macroergonomics philosophy ensures adequate consideration for organizational design and management issues (Hendrick, 1991).

PE specifies that end-users should be actively involved in planning and implementing ergonomics solutions. The concept of PE has its origin in discussions between Noro and Kogi in Singapore in 1983. Kogi proposed the term "participatory ergonomics" and then Noro solidified the concept in a workshop in Toronto, Canada, in 1984. Since then there has been a steadily growing interest in using PE for implementing ergonomics at work. PE has become familiar among ergonomists around the world, and it is consistent with cross-cultural participatory paradigms (Noro & Imada, 1991; Noro & Kogi, 1985).

PE is an increasingly growing field of ergonomics and of organizational design and management. Since its introduction, it has become more and more acknowledged (Imada, 1991). Brown (1993) argues that PE will lead to positive changes in productivity, the quality of working life, and a better realization of human potential. The more committed the organization is to PE, the more likely it is to produce a sustainable increase in productivity. Results from a Volvo Plant show that it is possible to create humanized work that is also efficient (Engstrom, Johnsson, Jonsson, & Medbo, 1995).

PE is principally the most often used methodology in the optimization of organization and work system design (Brown, 2002). To adopt PE, it is essential that the top management is committed and supportive (Brown, 1990).

Allard, Bellemare, Mountreuil, Marier, and Prevost (2000) have designed and established ergonomics groups for identifying and controlling musculoskeletal problems. Each team made interventions in high-risk situations and implemented corrective measures. To improve working conditions in office work, Vink and Kompier (1997) designed a participatory ergonomics program. A steering committee and a small ergonomics team were established. The designed structure was successful and resulted in improvements in the design and redesign of workplace ergonomics. Using participatory action research methodology, Rosecrance and Cook (2000) conducted a study on preventing work-related musculoskeletal disorders in the newspaper industry. In this study, an ergonomics committee, which included representatives of different departments, was established. The results showed that participatory ergonomics could contribute to the development and implementation of ergonomics solutions aimed at reducing risk factors of work-related musculoskeletal disorders. In an office automation project, Haims and Carayon (1998) implemented a participatory ergonomics program. In this study, an ergonomics team consisting of 12 members, called ergonomics coordinators, was established. Using behavioral cybernetics principles, external ergonomics experts succeeded in training internal ergonomics experts during the period of the project.

In the present study, an ergonomics intervention program was conducted in an Iranian manufacturing plant, using a participatory approach to improve working conditions and the workplace. The study was conducted in a medium-sized enterprise; a PE intervention model was designed and applied during an 18-month period with the following objectives:

- Improving working conditions:
  — Reducing musculoskeletal disorders (MSD) and
  — Improving the physical and chemical environment;
- Improving quality:
  — The quality of working life and
  — The quality of products;
- Increasing productivity.

In order to validate the obtained results, a similar factory was selected as control in which non-PE approaches were applied. As this study was considered a kind of interventional research in an industrial domain, after a deep investigation and an analysis of all alternatives, finally, two similar factories, A and B, were selected as the case and control factory respectively. These two factories were producers of hospital and medical furniture equipment and

were located in the south of Tehran, the capital of Iran. There were 80 shop floor employees in the case factory (A) and 75 in the control factory (B). In factory A, the PE intervention model was applied. In factory B, which had a routine top management decision-making style, an external ergonomist (the first author of this paper) acted as a change agent for proposing improvement changes for selected problems, which were found during the analysis phase. To evaluate the effectiveness of the designed PE model, in addition to assessing before- and after-intervention results, a comparison of the whole process of the PE model with the control factory was made. The use of some defined indices and variables proved to be a good measure of validity for the applied PE model.

2. METHODS

In order to implement the participatory ergonomics model, the following five-phase activity was designed and implemented.

2.1. Phase 0: Design of the Model. Duration: 6 Months

This phase included the development of a theoretical participatory ergonomics model for improving working conditions, quality, and productivity. The model was based on a Supportive Expert Team (SET, Figure 1) and a team-based structure for implementing the model (Figure 2), which received knowledge support from SET and cooperation of a Steering Committee (SC) and Action Groups (AGs).

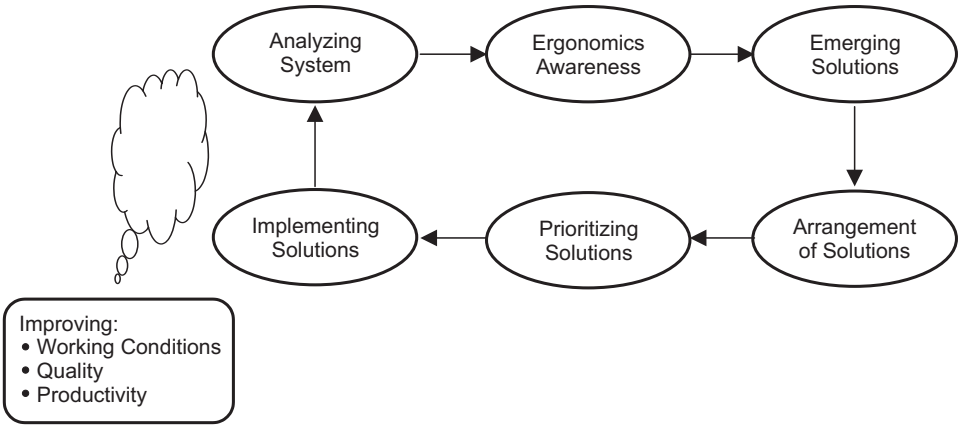

Figure 1. A participatory ergonomics model.

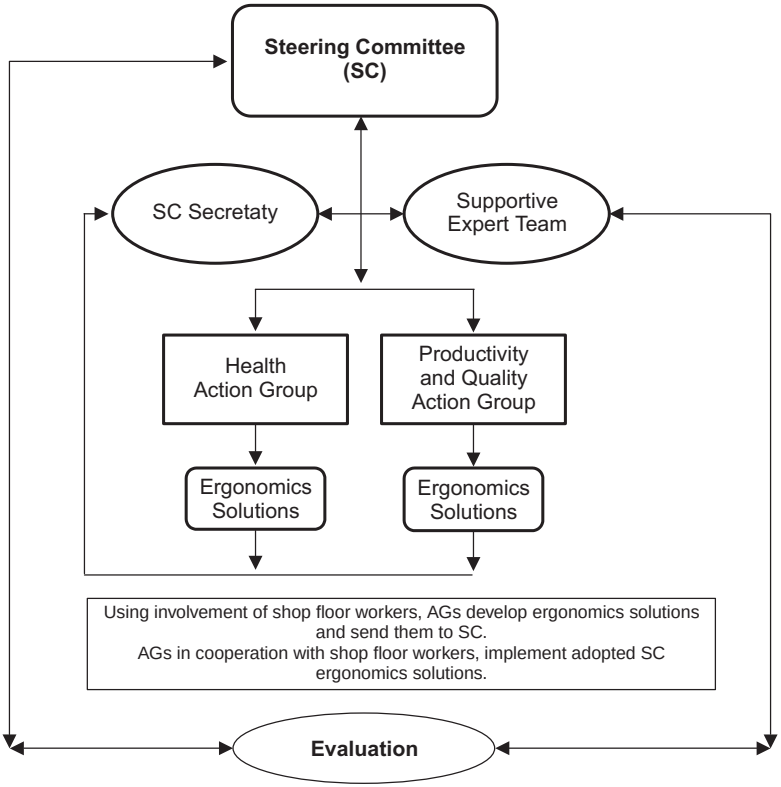

Figure 2. A team-based structure for implementing a participatory ergonomics model. *Notes.* AG—action group.

According to Nagamachi (1995), success in implementing participatory ergonomics requires participation, structure, ergonomics methods, and tools.

In practice, the following team-based structure was adopted in plant A, on the basis of teamwork effectiveness. The management appointed some of their employees to participate in the ergonomics project. The employees were divided into two Action Groups (AGs) and were responsible for improving working condition at different work sites. Each action group had 7 members. In order to provide and maintain a vision, communicate the vision, and support the AGs in their activities, a Steering Committee (SC) was formed in plant A. The SC consisted of the top manager, financial manager, production manager, and two top manager consultants. The management appointed the first author of this paper as the SC secretary. AGs were responsible for assessing workstation problems, developing an ergonomic improvement plan, and implementing the plan after the SC approved it. They had to make regular evaluations of their progress according to the project goals and objectives and to document the results.

During this and the next phase a questionnaire was developed as an instrument for evaluating the team's progress. The teamwork questionnaire included 20 questions on different aspects of teamwork. The main questions asked were related to the following issues:

- Appropriate size of the work team;
- The abilities of team members, including technical expertise, problem solving, and decision making, personal and interpersonal skills;
- Clarity of roles in the team;
- A vision and commitment to it;
- Establishment of a special goal at team level;
- Leadership and structure at team level;
- Accountability of team members at both individual and team level;
- Evaluation and reward system in the team;
- Development of high mutual trust in the team;
- A continuous learning process as one of the main functions of the team;
- Willingness to protect each other and maintain team identity;
- Conflict resolution in the team;
- Changes in attitude towards the organization;
- Behavioral changes at both personal and team level;
- Sense of ownership toward work done by team members.

Likert scaling was used in the design of the teamwork questionnaire and the following steps were taken:

- Scale items compiled, a 5-point continuum (*very good*, *good*, *neither good nor bad*, *bad*, *very bad*);
- 22 respondents were selected and asked to fill in the questionnaire;
- The total score for each respondent was calculated. The following scores were assigned for the 5-point scale: *very good*—5, *good*—4, *neither good nor bad*—3, *bad*—2, *very bad*—1;
- The test-retest method was used to test the reliability of the questionnaire.

Every other month, the SET evaluated the progress of the teamwork in the case factory.

The complete functions and responsibilities of the SC, AGs, and the SET are presented in Table 1.

TABLE 1. Functions and Responsibilities of the Steering Committee (SC), Action Groups (AGs), and the Supportive Expert Team (SET)

SC	AGs	SET
Organizing AGs Setting policies and administrative procedures, including time, place, and budget for AG activities; mechanism of AG interaction and documentation procedure Designing a rewards system for motivating AG members Evaluating project progress Reviewing and approving AG-proposed plans	Surveying ergonomics problems at their workplaces together with the people involved Developing feasible and cost-effective intervention plans for improvement Designing implementation of project plans, using a standard format (LFA). Sending project plans for approval to the SC. Implementing the approved projects at their work site, using available resources and involving the people concerned Evaluating their achievement, based on group progress, the results of ergonomic improvement, and the individual performance of group members	Providing leadership and support of AG activities via SC Familiarizing AGs with problem solving and team working techniques Teaching AGs ergonomics principles and techniques Evaluating project progress in cooperation with SC

Notes. LFA—Logical Framework Approach.

2.2. Phase 1: Analysing System. Duration: 3 Months

This phase included a holistic analysis of the current situation in the case and control factories, familiarization with their routine activities and measurement of selected indices and variables:

- Assessment of some selected organizational indices such as the amount of waste of raw material (the Productivity Index), rejects and reworks of finished products (the Productivity Index), and the frequency of unconformities (the Quality Index);
- Measurement of environmental factors such as lighting (lx), noise (dB), iron oxide fumes (mg/m3); and toluene concentration (ppm);
- Assessment of personal indices such as the quality of working life score, using a standard questionnaire based on Walton's (1973) quality of work life model, and pain score, using a body map.

All of the aforementioned indices and variables were initially selected by the SET in the primary design stage of the PE model (phase 0) and measured simultaneously, before phase 2, and after phase 3 in the case and control factories.

2.3. Phase 2: Ergonomics Awareness. Duration: Throughout the Project (18 Months)

This phase included activities such as justifying the project during phase 0 (ergonomics awareness of decision makers in the case factory), which continued throughout all phases, especially in the design and implementation of ergonomics training for employees in the form of workshops. However, the main part of the ergonomics awareness program—aimed at creating workers' awareness regarding ergonomics issues—started after phase 1.

In the case factory, based on primary discussions with the top manager and his associates, the ergonomics training program was designed and implemented with full support of top management. The objectives of this program were to acquire new knowledge and skills, to change the attitude towards more safe and healthy behaviours, and finally to develop ergonomics awareness among employees to improve working conditions collectively.

The training program was implemented by the SET in close cooperation with the SC. The key feature of the program was the introduction of ILO ergonomics checkpoints as a basic document for learning applied ergonomics and then improving working conditions.

2.4. Phase 3: Implementing Solutions. Duration: 6 Months

This phase included implementing ergonomics solutions, using local resources in a participatory approach. After developing ergonomics awareness, AGs with the knowledge support of the SET and the SC, designed and implemented ergonomics solutions (Figures 1 and 2).

2.5. Phase 4: Evaluation. Duration: 3 Months

In order to evaluate the degree of success or failure of the ergonomics intervention process, the defined indices and variables, which were selected in phase 1, were measured before and after intervention in both case and control factories. The team-based structure for implementing the PE model was designed in such a way that the evaluation process was a routine activity of the SC and AGs (Figure 1, Table 1). After the complete implementation of the PE model, the SC secretary presented the obtained results in a workshop for the SC and AGs members and the weaknesses and strong points were discussed.

3. RESULTS

As part of the evaluation process, during phases 0 and 1, a questionnaire was developed as an instrument for evaluating teamwork progress. The correlation coefficient between first and second measurements was equal to $r = .88$, $p < .05$. In order to assess agreement between before and after responses to the questions of the questionnaire, the kappa agreement coefficient was used and kappa values between .3 to .9 were obtained from all questions, which was significant at $p < .05$.

After successfully testing the designed questionnaire, including its validity and reliability, the questionnaire was used to evaluate teamwork progress. According to the scoring scheme, every respondent could acquire a total of 100 points in the best conditions as a team member ($20 \times 5 = 100$). The results showed a positive trend during the last 6-month period. In this period, the mean total score of team members increased from 74 to 85.

During phase 2, a total of 100 hrs of ergonomics training in the form of workshops and on-the-job training were conducted in the case factory.

Regarding improvements in the working conditions, quality improvement of products, and increasing productivity, all parties concerned considered the overall performance of AGs during phase 3 as very remarkable. With the administrative support of the SC and scientific support of the SET, they designed and implemented several low or no cost ergonomics solutions using local resources. So far, these solutions include a redesign of workstation layout, improvement of lighting (both natural and artificial), sanitation of workplace facilities, new arrangement for collecting and storing waste materials, painting factory indoor surfaces, reduction in noise, improvement of indoor air quality through a reduction of vapor and fume concentrations in indoor atmosphere, and a suggestion of a job rotation routine for high risk jobs. A summary of the obtained results, according to measured indices and variables, before and after intervention, is given in Table 2.

In addition to these achieved results, improvements in sanitary facilities were noticeable: The old facilities were repaired and in some cases new ones were built. Moreover, housekeeping was made a routine activity in the entire plant, using a specially developed checklist. Furthermore, defining new solutions for improvement became a routine activity of the AGs and it is hoped that all measured indices, especially quality and productivity, will continue to improve in the future.

TABLE 2. Summary of Improvements Due to Implemented Ergonomics Solutions in Factory A

Improvement	Before Intervention	After Intervention	Final Results
Reduction in wastage of raw material (%) —Productivity Index	8–10%	5%	3–5% reduction
Reduction in reworks (%)—Productivity Index	18%	10%	8% reduction
Unconformities (per unit)—Quality Index	25%	15%	10% reduction
Average lighting (lx)—in all workstations	99	252	over 250% increase
Iron oxide fumes (mg/m^3)—Forging workshop	1.2	1	20% reduction
Toluene concentration (ppm)—Saddlery workshop	300	<50	over 600% reduction
Noise reduction (dB)—Cutting workshop	95	90	5 dB reduction
Musculoskeletal discomfort score	41	38	7% reduction
Quality of Working Life (QWL) score	153	152	No significant change

As mentioned before, in order to validate the obtained results, a similar plant (factory B) was selected as control, in which a non-PE approach was applied. Despite the presence of a change agent (the first author of this paper) and a full report of the measurement results of indices and variables (phase 1), which indicated nonergonomics conditions at work, no significant improvement was made during the project. This was probably due to lack of awareness regarding benefits of ergonomics and its contribution to health, safety, and productivity among both management and employees. Lack of motivation among the people concerned as well as weak enforcement of safety and occupational health regulations by responsible authorities could be considered as reasons for unchanged conditions in the control factory. As a result, unfortunately, the differences between first and second measurements (before and after intervention) were not significant in all measured variables and indices in the control factory (Table 3).

After implementation of the PE model in the case factory, the SC secretary, in a session in which the SC and AGs members were present, presented the various improvements that were made by AGs. It was concluded that ergonomics training was a key factor in continuing the ergonomics process in the case factory. Also, management commitment and support was a vital prerequisite for continuous improvement. Establishment of a new action group for considering ergonomics in the new facilities of the factory was one of the critical results of the session.

TABLE 3. Status of Measured Indices and Variables Before and After of Intervention in Factory B

Indices/Variables	Before Intervention	After Intervention	Final Results
Wastage of raw material (%)—Productivity Index	10%	10%	No change
Reworks (%)—Productivity Index	15%	15%	No change
Unconformities (per unit)—Quality Index	20%	20%	No change
Average lighting (lx) in all workstations	206	206	No change
Iron oxide fumes (mg/m^3)—Forging workshop	1	1	No change
Toluene concentration (ppm)—Painting workshop	200	200	No change
Noise reduction (dB)—Cutting workshop	100	100	No change
Musculoskeletal discomfort score	39	39	No change
Quality of Working Life (QWL) score	190	181	5% reduction

4. DISCUSSION

According to Wilson (1991), one of the most important requirements for a participative approach to the implementation of ergonomics solutions is the motivation of the workforce and its competence at the individual and team levels. These characteristics cannot be imposed but they must slowly be allowed to grow through learning and involvement. This was the goal of the team-based structure for implementing the participatory ergonomics model in factory A, which showed very positive results. The SC and the AGs, based on the knowledge that they acquired through several training workshops, could develop an action plan and implement ergonomics solutions aimed at improvement. At the same time, it was the beginning of an organizational change and of preparation for other changes in the whole working environment. According to Halpern and Dowson (1997) a participatory ergonomics program, with multidisciplinary participation (similar to the team-based structure of this study), is one approach by which a company can weave together its manufacturing objectives of quality, productivity, safety, and cost containment to achieve effective production and injury reduction.

According to Moore and Grag (1996), using participatory ergonomics teams (similar to AGs in this study) is an effective way and may contribute to ergonomic improvements. In this study, one of the main obstacles towards successful performance of established teams was shortage of time due to work overload of AGs members. This constraint was also referred to in the previous studies (Moore & Grag, 1996).

Establishment of the SC was one of the vital requisites for adopting a participatory ergonomics approach. The SC provided necessary information to the AGs regarding financial resource availability for implementing change. It also provided easy communication and access to the authorized people at the company.

Workers participation creates ownership of the new ideas and helps people become an active part of the process, rather than having it dictated from above (Getty & Getty, 1999). Accordingly, forming AGs and allowing them to learn and think about their working conditions and deciding to change them if necessary, with the help of a Supportive Expert Team (SET) as facilitator, has shown to be among the most successful strategies.

The results showed a positive trend between the first and second measurements (before and after the intervention), in all implemented solutions. However, due to limited financial resources, low literacy and socio-economic status of shop floor employees, instability of the market, and high management turnover, the change process towards better working conditions and finally increased productivity and better quality was slow.

According to our experience, a supportive climate based on full commitment of top management, training of the people involved, endurance (patience), and persistence of the SET were significant contributing factors for success. Furthermore, good communication with all levels of the organization was also a prerequisite for enabling ergonomic improvements to be made, which resulted in higher productivity and better quality. This could be regarded as a sustainable strategy towards basic changes in working conditions in industrially developing countries, such as Iran.

In comparison with a non-PE approach, using top management enforcement and external ergonomists as change agents for finding and solving internal problems, application of such localized models could be considered as a provider of a more humanized work environment and also a more cost-effective and efficient approach.

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