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A Comparison of the Effects of Ergonomic, Organization, and Education Interventions on Reducing Musculoskeletal Disorders in Office Workers

Mohammad Hassan Safarian[1], Fatemeh Rahmati-Najarkolaei[1,*] and Alireza Mortezapour[2]

[1]Health Research Center, Lifestyle Institute, Baqiyatallah University of Medical Sciences, Tehran, Iran
[2]Department of Ergonomics, School of Public Health, Hamadan University of Medical Sciences, Hamadan, Iran

[*]*Corresponding author*: Health Research Center, Lifestyle Institute, Baqiyatallah University of Medical Sciences, Tehran, Iran. P.O. BOX: 19395-5487, Tel: +98-2182482468, Fax: +98-2188600062, Email: fatemeh_rahmati@bmsu.ac.ir

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Abstract

Background: One of the most important and the most common health problems among office workers and computer users is the risk of developing musculoskeletal disorders (MSDs).
Objectives: This study aimed at evaluating risk factors of MSDs and determining the effectiveness of the ergonomic, organization, education interventions on reducing MSDs in the office workers of university offices of Tehran, Iran.
Methods: This quasi-experimental study was conducted on 221 employees during spring 2015 to summer 2016. Participants were categorized to four groups by simple random sampling: control group (n = 55), recipients of education interventions (n = 57), recipients of organization interventions including job enrichment, job enlargement and job rotation (n = 54), and recipients of ergonomics interventions (n = 55). Rapid office strain assessment (ROSA) and Cornell musculoskeletal discomfort questionnaires (CMDQ) were used for data gathering. Data were analyzed by one-way analysis of variance (ANOVA) and paired-samples *t*-test using the SPSS version 16 software.
Results: After the intervention, a significant difference was revealed in the final mean score for ROSA in the two groups of recipients of education and ergonomic interventions ($P < 0.05$). Also, data revealed a significant difference in MSDs, including neck, shoulders, and hand/wrist, among ergonomics and education groups.
Conclusions: Educational and ergonomic interventions may reduce ergonomics risk factors of MSDs and prevalence of discomfort. However, according to the results, organizational interventions alone may not be more effective in reducing risk factors of MSDs and their discomforts. The effectiveness of multilayered interventions should be investigated in the future.

Keywords: Ergonomics, Health Education, Human Engineering, Musculoskeletal Diseases, Workplace

1. Background

One of the important groups of occupational injuries and disabilities in many developing and developed countries is musculoskeletal disorders (MSDs), which imposes high economic costs for societies. Given the significance of this issue, the World Health Organization (WHO) in 2013, ranked MSDs as the second most prevalent work-related disease (1). Furthermore, the literature has indicated the importance of controlling and reducing these problems around the world, which is currently a major challenge for ergonomic experts (2-4).

According to Moradi et al. (5), MSDs involving the back and waists were highly prevalent amongst mechanics, determined using the rapid entire body assessment (REBA) method. Also, shoulder problems is common amongst Iranian students (6). Another study indicated that MSDs involving the upper and lower limbs have high prevalence in Iran (7).

Studies conducted among office workers demonstrated that one of the most important and prevalent health problems in computer users is the risk of developing MSDs. National Bureau of Statistics of China announced in a report during year 2007 that 60 % of employees use computers in their workplace (8). It was also revealed that more than half of the employees in EU-member states used computers during their workdays (9). In several studies, using the computer has been associated with an increased prevalence of MSDs (10, 11).

Repetitive activities, applying excessive force, poor working posture, contact pressures and physical fatigue are among the most important physical risk factors of MSDs in most jobs (12). In computer users, in addition to the aforementioned factors, there are other factors, including personal factors, such as age, gender, obesity, physical activity, and smoking; and factors related to the design of the workstation, such as position of the monitor, duration of using a computer, numbers of breaks, method of using the keyboard, as well as psychosocial factors (13-15). Designing an ergonomic work space by using engineering approaches is one of the interventions intended to completely eliminate environmental risk factors of the office environment. Furthermore, the use of organizational controls, such as holding workshops to raise knowledge of employees about ergonomic risk factors and about setting up workstations by the employees themselves, as well as job rotation, have been introduced to reduce the risk of MSDs (15, 16). If possible, the combination of educational interventions in engineering interventions can serve as the most important and effective factor to improve ergonomic conditions of office work stations (17-20).

In recent studies, the role of job design in increasing job satisfaction of office workers was well-evaluated (21-24). Ergonomists suggested that in designing interventions to reduce MSDs, the physical and psycho-social aspects of work must simultaneously be concerned (25). One suitable method to reduce and balance psychological risk factors of the workplace is job design, which can be achieved through job rotation, job development, and job enrichment (26). The study of Piranveyseh er al. (27) showed that certain psycho-social factors may be related to the increase in MSDs prevalence. Thus, one must pay simultaneous attention to the work's physical and psychosocial aspects. In another study, Yip et al. (28) revealed that various psychosocial factors, such as monotonous work, lack of job satisfaction, and weak support among colleagues can increase complaints of lower back pain.

2. Objectives

Based on the high requirement of office workers for improving their working conditions, the present study was conducted with the following aims: (1) Assessment of the prevalence of MSDs and evaluation of ergonomic risk factors for office workstations, and (2) analysis of the effectiveness of education, ergonomic, and organization interventions, on reducing MSDs among the staff of Tehran University of Medical Sciences (Tehran, Iran), separately.

3. Methods

3.1. Study Population

This quasi-experimental study was conducted on 240 employees of Tehran University of Medical Sciences with work experience of over one year with more than three hours of working with computers per day. Data was gathered during spring 2015 to summer 2016. In total, the sample size was calculated as 240 participants, who were allocated to four groups.

According to the sample and mean and standard deviation (SD) (3.96, 3.59, 1) of the groups (G1, G2), the power of the study was calculated above 80%. Therefore, the sample size is approved (29).

In this study, the statistical population was 550 participants. Overall, 450 participants had the inclusion criteria and others worked in other job positions. Then, after holding meetings with the heads of each of the units, the cooperation between workstations and communication with the practitioners of every station, participants were divided to four groups. Of the total population (450 participants), 95 participants were allocated to the control group, 150 participants to the education intervention group, 120 participants to the organization intervention group and 85 to the ergonomics intervention group. Finally, after determining the study population, the inclusion criteria were used for the allocation of samples to each group, and finally 60 participants for each of the four groups (240 in total) were selected using the simple random method.

Inclusion criteria were work experience of over one year with more than three hours of working with computers per day. Participants s with a history of severe trauma or fracture of the neck, elbows, back and knees, a history of diseases affecting the musculoskeletal system, SLE, osteoarthritis, diabetes, and gout were excluded.

A total of 240 questionnaires were distributed among participants before the interventions. At the end, after four months of intervention, 221 cases entered the statistical analysis stage. Overall, 19 participants were excluded for several reasons, such as being uninterested to continue participation. Considering ethical approval codes, this study was approved at session 418, by the deputy of research and technology of Baqiyatallah University of Medical Science on the 9th of August 2015. Before data gathering, informed consent forms for participation in the study were completed by the participants. After sampling, the study was conducted in the following three steps:

Step one: Initial Assessment of the work environment:

Demographic and job characteristics: For this purpose, a questionnaire was designed to collect information, such as age, gender, height, weight, and work experience.

3.2. Studying the Prevalence of Musculoskeletal Disorders

Cornell musculoskeletal discomfort questionnaire (CMDQ) was used to study the degree of musculoskeletal discomfort. The CMDQ is self-administered and provides information about the existence and repetition rates of discomfort, severity of discomfort and its effect on work ability. After determining each section of the questionnaire, the numbers of the three sections must be multiplied together and the final results would be a number between 0 and 90 (30). Reliability and validity of the Persian version of the questionnaire was determined and reported as acceptable by Afifehzadeh-Kashani et al. (31).

Assessing ergonomic risk factors for office workstations: For this purpose, the rapid office strain assessment (ROSA) method was used, which had been designed by Sonne et al. (32) to identify risk factors for office work and setting priorities for achieving the optimal balance between staff and equipment at a workstation. The validity of the method was confirmed by numerous studies (33-35).

Step two: Implementation of interventions:

The present study was conducted on four separate groups, including the control group without receiving any intervention (n = 55), education intervention group (n = 57), the organization intervention group with a focus on job enlargement, job rotation, and job enrichment (n = 54), and the ergonomic intervention group (n = 55). The study flow diagram is presented in Figure 1. It should be noted that educational intervention was also a part of administrative controls. Given the aim of the present study, which is a separate evaluation of various ergonomic intervention methods, educational and organization interventions were assessed separately. The interventions were administered during a span of two months at the same time, and were as follows:

Education intervention: For this purpose, training manuals with the participants of office ergonomics were distributed among participants. The manual included the following tips: Identifying neutral and inappropriate postures, how to adjust the chair and make appropriate postures while working on a chair, how to set up and arrange objects on the desk, proper positioning of the telephone in relation to the position of the individual, the proper use of the telephone, correct posture for using the mouse and keyboard as well as their proper placement on the desk, the correct way of using the mouse and the keyboard, the best angle and distance between the monitor and the user while working, and the proper placement of holder page on the desk. All of these were selected based on the rearrangement of the workstation by the personnel themselves with regards to the risk factors under study by the ROSA method and using the guideline on office ergonomics, as provided by the Canadian Standards Association (36). In addition, in order to introduce employees to the desk exercises and for a regular practice of these moves, the ErgoPro software was installed on all of their computers.

Organization intervention: These interventions were administered according to job enlargement, job enrichment, and job rotation. Job enlargement and enrichment are motivational factors that increase motivation and satisfaction in individuals to better perform their assigned tasks. Job enlargement and job rotation add more variety of tasks and activities to the job, so that the job will not be tedious. In the present study, the scope of duties and responsibilities assigned to participants in the organization intervention group was increased to prevent the work from being monotonous. For this purpose, the participants, in addition to their routine tasks, were asked to do other tasks on a rotating basis, such as delivering administrative letters, doing a roll call, and following up on work shortcomings and welfare of colleagues. Also, in some cases, tasks were performed by taking turns and the participants experienced different conditions and responsibilities.

On the other hand, job enrichment adds further incentives to the work, deepens the job and includes more control, responsibility, and discretion on how to perform a task. This method, unlike job enlargement that easily adds more variety to work, gives individuals greater authority. For this purpose, participants were asked to be present in decision-making meetings about improving the current situation with the supervisor and the manager. Furthermore, advanced computer courses were designed and participants were asked to increase their knowledge in this field by taking part in the classes. They were also asked to voice their suggestions for resolving the shortcomings of office tasks on a weekly basis. Holding specialized classes related to their jobs for increasing their knowledge was another method of intervention in this part.

Ergonomic intervention: In the present study, an ergonomic intervention group was selected to investigate the effect of changes in office workstation by rearranging, replacing, and adding some equipment. Some of these ergonomic interventions included replacing the keyboard, replacing or adding a mousepad, adjusting the workstation, such as adjusting the height and angle of the monitor, relocating the telephone and ergonomic arrangement of equipment on the desk, distributing ergonomic footrests, an inclined plane for raising the surface of study to a

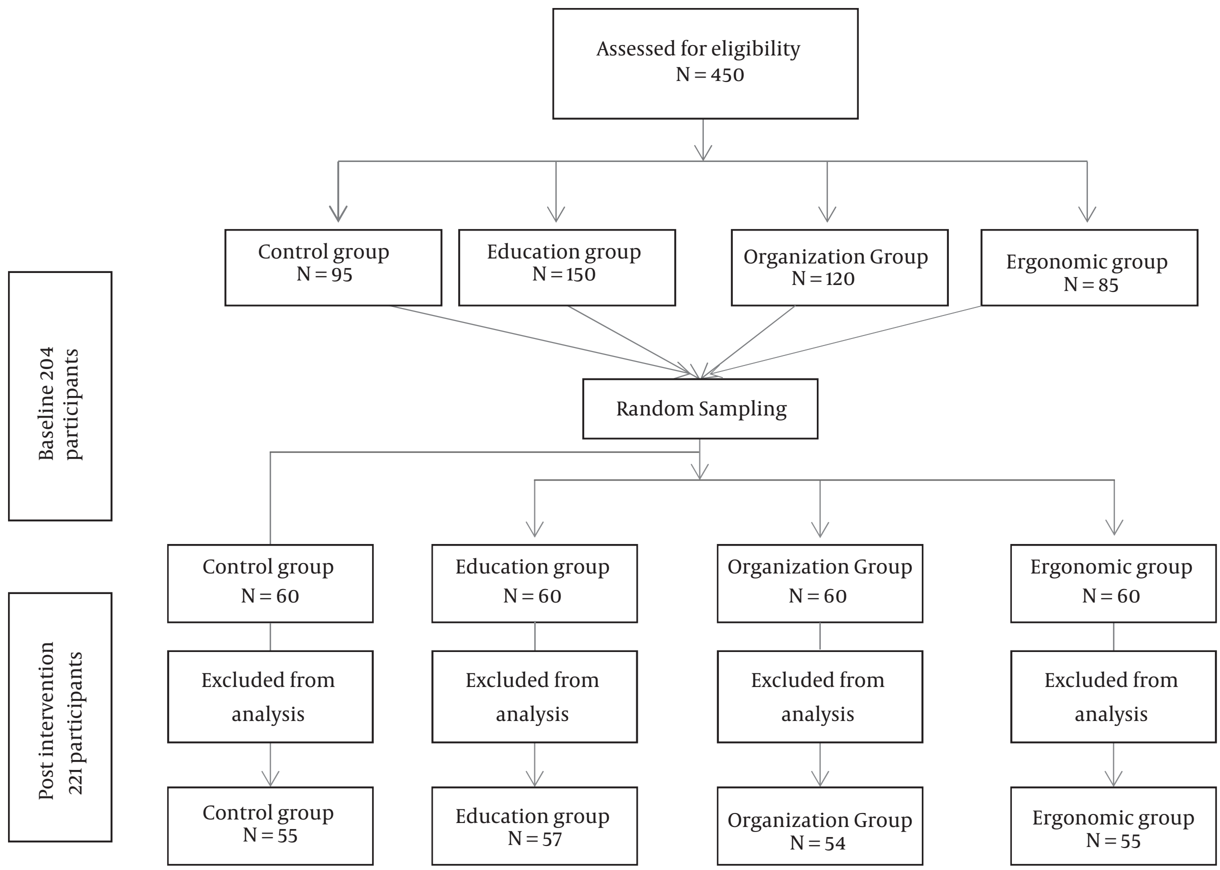

Figure 1. Study flow diagram showing the steps of the study

higher level, distributing spine fits (ergonomic seat back support), replacing the chair and adjusting the light of the work station to prevent glare. The interventions were administered according to the ROSA method and whether all or a part of them were considered necessary for the workstation. At least one or more of the aforementioned interventions were administered at each workstation of this group.

Step three: Evaluating the effectiveness of interventions:

In order to determine the effectiveness of the interventions on office ergonomic risk factors of musculoskeletal discomforts, the evaluations were once again conducted first through the ROSA and then by the CMDQ, four months after the last day of administrating the interventions. The results of the post-test were compared with the pretest. All evaluations were similarly conducted on the control group. For bias prevention, interventions were conducted simultaneously in four groups.

3.3. Data Analysis

The SPSS version 16 was used for analyzing data in the present study. Normal distribution of data was done using the Kolmogorov-Smirnov test or K-S (P value $>$ 0.1) (37). Also, according to central limit theorem, sample size of more than 30 can be considered as normally distributed thus in this study, parametric statistical test was used (38). In order to compare the mean demographic characteristics, such as age, height, weight, work experience and body mass index among the three groups and comparing the groups, the one-way ANOVA was used. homogeneity of variances was checked using Levene's statistic test (P $>$ 0.05).

For comparing the mean score for ROSA and the mean discomfort as quantitative variables before and after the intervention, the paired *t*-test was used. Also, for comparing ROSA scores before and after the intervention, one-way ANOVA was used. All tests were conducted at a 95% confidence level.

4. Results

The demographic characteristics of the participants in each study group is presented in Table 1. The results of the statistical test showed that mean of variables, such as age, work experience and body mass index (BMI) did not have a significant difference ($P > 0.05$).

Comparative results of the mean score for the MSDs rate, ROSA and its components in workstations of employees before and after the intervention are presented in Table 2. Results showed no significant differences in total variables, except knee disorders ($P < 0.01$) in the pre-test. Equality of variances assumption was tested using Levene's test ($P = 0.06$) before interventions. However, in the post test, mouse and keyboard ($P < 0.01$), ROSA scores ($P < 0.01$), and knees ($P < 0.05$) were significant.

Also, the difference of the mean of the mouse and keyboard ($P < 0.01$), total ROSA score ($P < 0.0$) and monitor and phone were significant ($P < 0.05$). There were significant differences in mouse and keyboard and ROSA scores betweeen organizational and ergonomics groups ($P < 0.001$). In the mouse and keyboard, only ergonomics intervention was meaningful compared to the control group.

Furthermore, in the ergonomic and education groups, there were significant difference in the ROSA scores ($P < 0.001$) in the neck, shoulders, and hand/wrist ($P < 0.05$).

The mean differences of MSDs neck ($P < 0.01$), shoulders $P < 0.01$), and hand/wrist ($P < 0.01$) were significant. In the neck areas, betweeen organizational and ergonomics groups, there were significant differences ($P < 0.001$). Also, in the shoulders area, betweeen organizational and ergonomics groups, there were significant differences ($P = 0.01$).

Also, the results before the intervention showed that the highest score in the control group, obtained from the Cornell questionnaire, belonged to upper back (31.09), shoulders (23.37), and neck (19.26); in the educational intervention group, the highest score belonged to upper back (28.2), neck (25.3), and shoulders (24.1). In the organizational intervention group, the highest score belonged to upper back (29.6), neck (24.73), and shoulders (21.18) and in the ergonomics intervention group, the highest score belonged to upper back (27.82), neck (27.08), and shoulders (25.54).

5. Discussion

This study aimed at investigating risk factors of MSDs and comparing interventions of the ergonomic, organization, and education among staff of Tehran University of Medical Sciences. Results indicated that after interventions, a significant difference was revealed in the final mean score of ROSA in the ergonomic and education groups. However, the final mean score of the groups after the intervention showed a considerable decline.

In MSDs, the amount of these discomforts had significant differences in three body parts (neck, shoulders, and hand/wrist) among the 11 areas under study in four groups. In other parts of the body, an amount of decline was observed, yet was not statistically significant. The results showed effect of ergonomic and education interventions for the neck, shoulders, and hand/wrist were significant.

The evaluation of ergonomics risk factors before the intervention showed that the mean score for ROSA at the workstations was four to five, which is an average risk. Furthermore, average risk was found in the Farrokhi et al. study (39).

This is while the mean score of ROSA in the control group did not show any significant intervention. These results indicate the effectiveness of all interventions, excluding organization group in reducing ergonomic risk factors at the workstations. The effect of ergonomic intervention was better than others.

Lack of knowledge about ergonomics among employees and the use of non-ergonomic equipment and lack of attention to ergonomic issues in the workplace may be the main reason for the high risk score for ergonomic workstations before the intervention. It is clear that raising the employees' knowledge about the standard condition of the workstation and adjusting the workstation by themselves as well as creating physical changes in workstations and replacing some non-ergonomic equipment can reduce the risk level and amount of musculoskeletal discomforts in certain areas of the body (40). These results are consistent with studies that had used educational and ergonomic interventions to reduce risk factors that cause MSDs. In Robertson et al. (19) study, it was found that the use of educational intervention and adjustable ergonomic chairs will favorably improve the condition of workstations. Jahangiri et al. (41) also noted that using combined ergonomics and educational interventions is a more appropriate approach compared to the use of educational intervention alone in order to reduce MSDs. Nasiri et al. (35) in a study aimed at evaluation of the effectiveness of ergonomic interventions among office workers showed that using ergonomics and educational intervention could reduce ergonomic risk factors and the prevalence of MSDs in some areas of the body. The results of the present study were inconsistent with studies conducted by Amick et al. (42) and Ali Arabian et al. (43), in which they did not

Table 1. Demographics and Occupational Characteristics of the Employees (n = 221)

Variables	Mean	SD	Min	Max	P Value
Age (y)					0.892
Control group	37.22	7.12	24	57	
Educational intervention	36.72	6.77	23	56	
Organizational intervention	36.26	6.72	25	54	
Ergonomics intervention	36.51	7.60	24	58	
BMI					0.633
Control group	25.52	3.99	16.53	34.17	
Educational intervention	25.94	4.23	18.37	38.06	
Organizational intervention	25.11	3.10	19.57	36.33	
Ergonomics intervention	25.46	3.14	19.12	34.60	
Work Experience (y)					0.152
Control group	12.14	6.45	2	29	
Educational intervention	9.73	5.66	1	25	
Organizational intervention	9.90	5.20	2	23	
Ergonomics intervention	10.87	6.53	1	28	

Table 2. The Mean of Outcome Variables at the Beginning, the End and Its Changes by the Four Groups Studied[b]

Variables	(G1, G2, G3, G4, P)[a]		
	Pre Test	Post Test	Diff
Chair	(4.35, 4.69, 4.81, 4.4, *)	(4.22, 4.48, 4.62, 4.49, NS)	(-.12, -.14, -.32, .00, NS)
Monitor and phone	(4.16, 4.08, 4.29, 4.16, NS)	(3.59,3.96, 3.69, 3.89, NS)	(-.49 ,-.05 ,-.6 ,-.27, *)
Mouse and keyboard	(4.16, 4.08, 4.29, 4.16, NS)	(2.94,3.46,2.85,3.61, **)	(-.31 ,-.11 1,-.69, -.14, **)
ROSA score	(4.92, 4.84,5.09,4.92, NS)	(4.4,4.74, 4.2,4.89, **)	(-.43, -.16, -1.09, -.03, **)
Neck	(25.3, 24.73, 27.08, 19.26, NS)	(19.94, 23.59,18.94, 20.06, NS)	(-5.42 ,-1.13, -8.13,.8, **)
Shoulders	(24.1, 21.18, 25.54, 23.37, NS)	(22.93, 21.18, 22.66, 24.77, NS)	(-1.16 ,0.00, -2.88 ,1.4, **)
Upper back	(28.2, 29.6, 27.82, 31.09, NS)	(27.51,28.07, 26.87, 32.26, NS)	-.76,-1.6, -.95 , 1.17, NS)
Arm	(5.47, 6.34,6.1,3.97, NS)	(4.9,6.00, 5.5, 3.79, NS)	(-.57,-.33 , -.6 , -.18, NS)
Lower back	(12.35, 14.12, 15.41, 12.79, NS)	(12.12,13.87 , 14.38,12.98, NS)	-.23,-.25 , -1.03 , .19, NS)
Forarm	(5.97, 7.79,7.85,5.44, NS)	(5.94,7.41, 7.2,5.37, NS)	(-.02,-.37, -.64 , -0.07, NS)
Hand/wrist	(16.5, 15, 21.14, 15.48, NS)	(16.07,14.48, 19.59,16.56, NS)	(-.42, -.51 ,-.95 ,1.08, **)
Buttocks	(4.97, 7.49,9.7,5.08, NS)	(4.69,6.77, 7.31, NS)	(-.28,-.71, -.58, -.06, NS)
Knees	(6.16, 7.12,11.26,6.5, **)	(5.38,6.88, 10.38,6.2, *)	(-.78,-.23 , -.88, -0.3, NS)
Thigh	(4.8, 5.64,9.5,4.72, NS)	(4.68,5.21, 5.52, 4.78, NS)	(-.12, -.43 , -.38 , .06, NS)
Legs	(6.02, 8.37,9.04,6.31, NS)	(5.55,8.13, 8.46,6.39, NS)	(-.47 -.23, -.58, .07, NS)

Abbreviation: NS, not significance.
[a] G1, education intervention; G2, organization intervention; G3, ergonomics intervention; G4, control.
[b] * $P < 0.05$, ** $P < 0.01$.

consider educational intervention alone as an appropriate method for reducing MSDs. The ergonomic intervention aimed at changing the work environment was more effective than the educational intervention. Education alone will not change the work station.

Other objectives of the present study included the evaluation of organizational intervention based on job enrichment, rotation, and enlargement on ergonomic risk factors and the prevalence of these discomforts. Results showed that the use of these methods for reducing risk factors and the prevalence of discomforts in office works is not very effective. The most important reason for this result is the ineffectiveness of interventions in the physical conditions of the workstation (44). Given the fact that in office tasks, the type of work and duties of employees are almost similar, use of the aforementioned methods alone and in a short span of time (4 months) cannot make changes in working postures and the amount of pressure on different areas of the body. As a result, the use of this approach on its own may not have an effect on ergonomics risk factors and the reduction of these discomforts. In recent studies, the effect of job design on increasing job satisfaction and mental power among office workers was well-evaluated (21-24); however, the effect of these factors on office ergonomics risk factors is not clear. Choobineh et al. (45) showed in their study that ergonomic interventions, including education and changes in workstations, only affect physical factors and cannot properly reduce psychosocial factors of work. Thus, given the fact that job improvement, enrichment and rotation approaches are a part of psychosocial factors of work, the ineffectiveness of these approaches alone on reducing the ergonomic risk factors in the ROSA method, which often considers physical factors, can be justified.

In the present study, different intervention methods (educational and ergonomic interventions), mostly related to physical and biomechanical MSDs risk factors and organization interventions including job enrichment, rotation, and enlargement related to psychosocial MSDs factors, were designed. These interventions were administered in separate groups and the effectiveness of each was separately determined, which can be considered as one of the strengths of this study. Weaknesses include failure to investigate psychosocial factors and the effect of interventions on reduction of these factors, low sample size, as well as the evaluation of the effectiveness of interventions in a short period of time. It is suggested that similar studies should be conducted with a combined design of ergonomics, education, and organization interventions for reducing all office ergonomics risk factors (physical, biomechanical, and psychosocial) and monitoring the administration of these interventions in a longer period of time.

5.1. Conclusions

The results of the present study showed the effectiveness of educational and ergonomic interventions in reducing ergonomic risk factors and the prevalence of discomforts among computer users. However, it was revealed that using organizational interventions, such as job enrichment, improvement and rotation alone is not an effective method for reducing ergonomics risk factors and the prevalence of discomforts. Simultaneous use of complex methods, such as ergonomic, educational and organizational interventions, among office workers may yield desirable results in reducing risk factors for musculoskeletal problems. It should be noted that this intervention must be on the supervision of ergonomics experts and also the type of job task must be considered.

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Footnotes

Authors' Contribution: Study concept and design: Mohammad Hassan Safarian, Fatemeh Rahmati-Najarkolaei; analysis and interpretation of data: Fatemeh Rahmati-Najarkolaei, Mohammad Hassan Safarian; drafting of the manuscript: Mohammad Hassan Safarian, Fatemeh Rahmati-Najarkolaei; critical revision of the manuscript for important intellectual content:, Fatemeh Rahmati-Najarkolaei, Alireza Mortezapour; statistical analysis: Fatemeh Rahmati-Najarkolaei.

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