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Research Article

Assessment of musculoskeletal disorders and mental workload among office workers in the automotive industry

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ABSTRACT

Evaluation of workplace ergonomics for office workers is significant for occupational health. Since office employees' work is often mental, this evaluation should include a mental workload assessment as well as a physical assessment. The purpose of this study is to examine the physical and mental workload of office workers of an automotive supplier company. This study was carried out on 250 office workers. The musculoskeletal and physical risks were investigated using Rapid Office Strain Assessment (ROSA) and Cornell Musculoskeletal Discomfort Questionnaire (CMDQ), and the mental workload was analyzed with NASA Task Load Index (NASA-TLX). Musculoskeletal disorder risk and mental workload levels were revealed by statistical analysis and examined on the basis of departments. The correlations between risk levels obtained by different methods and the effect of gender and age factors were also investigated. ROSA final score average was 3.69 which corresponds to a moderate risk level. 62.4% of the employees for the chair section and 64.4% of them for the keyboard and mouse section were at moderate and above risk levels. According to the CMDQ results, the body regions with the most discomfort were determined as the neck, upper back, lower back and right wrist. NASA-TLX scores showed that the highest mental workload occurs in office workers in Accounting, Maintenance and Purchasing departments. NASA-TLX scores were found to be correlated with the ROSA final score, but not with the CMDQ scores. Evaluating the musculoskeletal disorder risks and mental workload of office workers together and taking the necessary precautions were beneficial in terms of protecting the health of the employees.

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INTRODUCTION

Office employees work sitting at a desk and chair throughout the working day. Auxiliary elements such as phones or tablets are also used for office tasks which are generally performed at the computer. Office workers are exposed to some unsuitable postures while sedentary or

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standing work. This exposure creates the risk of musculoskeletal disorders (MSDs). Staying in unsuitable postures during long working hours further increases the risk of MSD [1]. MSDs are diseases related to the muscles, joints, tendons and nerves which effect body regions such as the neck, upper limbs and back [2]. MSDs are related to prolonged sedentary positions, time-pressured and stressful work, static and awkward postures, and repetitive movements that office workers are also often exposed to [3]. Workplace conditions need to be improved (both mentally and physically) to reduce MSDs and increase occupational health among office workers.

MSD symptoms and ergonomic risk factors of office workers with high computer use are examined with various questionnaires. In a study conducted with the Chinese Health Questionnaire and Musculoskeletal Symptom Questionnaire, MSD symptoms were found to occur most on the shoulder (73%), neck (71%) and upper back (60%) regions of office workers using computers. In addition, it was observed that psychological stress increased shoulder and upper back complaints, and increased workload increased waist complaints [4]. An online questionnaire application study on musculoskeletal discomfort and computer use in university staff reported the most common regions of musculoskeletal discomfort as the neck (60%), shoulder (53%) and lower back (47%) regions [5]. There is a relationship between the MSDs on the hand and arm regions and the way or duration of using the computer mouse and keyboard. The relationship between the MSDs in the shoulder and neck regions and computer use should also be examined further [6].

In addition to questionnaires, observational ergonomic evaluation methods are also applied to office workers who mostly use computers in their workplaces. These include ROSA, Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA). These assessment methods were found to correlate with the MSD risk levels estimated by the questionnaires [7]. In an ergonomic risk assessment study conducted on 102 office workers of a large-scale manufacturing company with the ROSA and CMDQ methods, the average ROSA final score was found to be 4.43. It was determined that the discomfort felt in the neck, back, waist and shoulder regions had a significant relationship with the office risk level [8]. In a similar risk assessment study, the average ROSA final score was calculated as 3.52. According to the results of CMDQ, the most uncomfortable areas were the neck, waist and back; CMDQ scores in these body regions were found to be correlated with the ROSA scores [9].

Improving the design of office furniture and equipment with which employees interact and some interventions including sitting, standing and walking are useful for reducing musculoskeletal discomfort and attenuating perceived physical and mental fatigue in office workers [1]. ROSA method was used to investigate the efficiency of an educational intervention program on office personnel in a university. ROSA scores were compared before and after the intervention aimed at raising awareness of the workers; it was found that the mouse, keyboard, monitor and phone scores decreased significantly [10]. In an intervention study with sit-stand desks, differences in sedentary behavior based on desk type and awareness of the importance of posture variation were assessed in call center workers. The use of sit-stand desks helped improvement in sedentary postures [3]. Under desk cycling as an intervention for sedentary office workers was also tested. However, no clear benefit of this intervention was found for musculoskeletal health and cognitive function measures [11].

There are studies evaluating both mental and physical burden among office workers in the literature. In a study examining the relationship between subjective mental workload and MSDs, the NASA-TLX scale and Nordic Musculoskeletal Questionnaire were applied to office employees working in a bank. Mental workload scores were found to significantly correlate with MSD rates [12]. In a large-scale study examining office workers' MSD risks using the Nordic Musculoskeletal Questionnaire, ROSA and NASA-TLX, the severity of discomfort in the shoulders, elbows, wrists, thighs and feet was associated with the final ROSA score. And some NASA-TLX subscales (effort, mental demand and performance) were associated with MSD symptoms in different body regions [13]. Apart from office workers, there are also studies on mental workload and MSD risks on manufacturing workers. In a study conducted with 303 employees in automotive manufacturing, the CMDQ, a lifestyle questionnaire and NASA-TLX were used together. It was determined that 70% of the employees experience MSD in at least one body region and there was a correlation between MSD and age, work experience, responsibility, lifestyle and time pressure [14].

The mental workload that some employees feel may cause them to work in postures that may pose a risk of MSD. Examining the mental and physical burden together will help reveal this situation. In a study conducted on sterile processing department employees who were exposed to the impact of many complex factors in the workplace, the MSDs of the employees were determined with the Nordic Musculoskeletal Questionnaire and ergonomic evaluation was made with the REBA method. In addition, the mental workload was determined with NASA-TLX. Eventually, it was found that the increase in mental workload worsened postures and increased the risk of MSD [15]. Computer users' mental effort was found to be associated with electromyographic changes in biomechanical responses, especially when the office workers do not use the chair's backrest [16]. In a study conducted on only 60 female computer users, ROSA, CMDQ, Carmen-Q and NASA-TLX methods were used together. The average ROSA final score was calculated as 5.54, and according to the CMDQ, the majority of workers experienced discomfort in the lower back, neck and right shoulder. Based on these regions, CMDQ and NASA-TLX scores were found to be correlated [17].

Even if the physical condition of the tasks stays the same, the mental workload can change. Because the perception of mental workload can be affected by some psychosocial work factors [18]. Some individual factors and personal characteristics such as gender, body mass index, extraversion and conscientiousness can be predictors for musculoskeletal disorders which can mediate the effect of body posture and mental workload of office workers. For example, women experience a higher rate of MSD and the mental workload that can directly affect the MSDs is more common in neurotic people [19].

The physical and mental workload created by the work on the employee together constitutes the work-related health of the employee. Some of the factors that possibly affect the physical and mental workload are working postures, working speed, stress, work equipment, and environmental factors. Some of these factors directly affect physical or mental workload, while others can affect both. All factors should be considered together in office workers who mainly perform mental work as well as physical work. In this way, the effects on employee health can be understood more clearly (Figure 1).

Studies in the literature mainly do not examine the physical and mental burden of office workers together. Most of the examinations on office workers generally used a single questionnaire method. This study aimed to investigate the work-related health of office workers, by examining physical office ergonomics risk factors and cognitive load levels, using a subjective mental workload scale, an observational assessment method and a questionnaire together, unlike the general literature on this subject. In addition, it is among the aims of the study to reveal the possible relationships between the methods that evaluate mental and physical load.

The main purpose of this study is to determine the MSD risk and mental load levels of office workers of an automotive supplier company. For this purpose, ROSA, CMDQ and NASA-TLX methods were applied. The data obtained from these methods were statistically analyzed to reveal the relationships between office ergonomic factors, MSD risks and mental workload levels.

This paper is organized as follows: The information about the participants and utilized methods are given in Section 2. The findings obtained with these methods are explained in Section 3. The results of the study are discussed and compared with the literature in Section 4. Finally, an overall conclusion is given in Section 5.

MATERIALS AND METHODS

Participants

This study was conducted in a company that produces mechanism, body and chassis parts for the automotive supply industry through different sheet metal part-forming processes. A total of 250 office workers from manufacturing and administrative departments were voluntarily involved in the study. The participants filled out a simple questionnaire (including age, gender and department information), a ROSA form, a CMD questionnaire and a NASA-TLX scale. All participants were given verbal and written information before signing an informed consent form and applying the questionnaires. The questionnaire and methodology for this study were approved by the Science and Engineering Research and Publication Ethics Committee of Bursa Uludag University (Ethics approval number: 2021-11).

The ages of the participants ranged from 21 to 59. The mean age is 34.8 (± 6.9) and 66.5% of them are men and

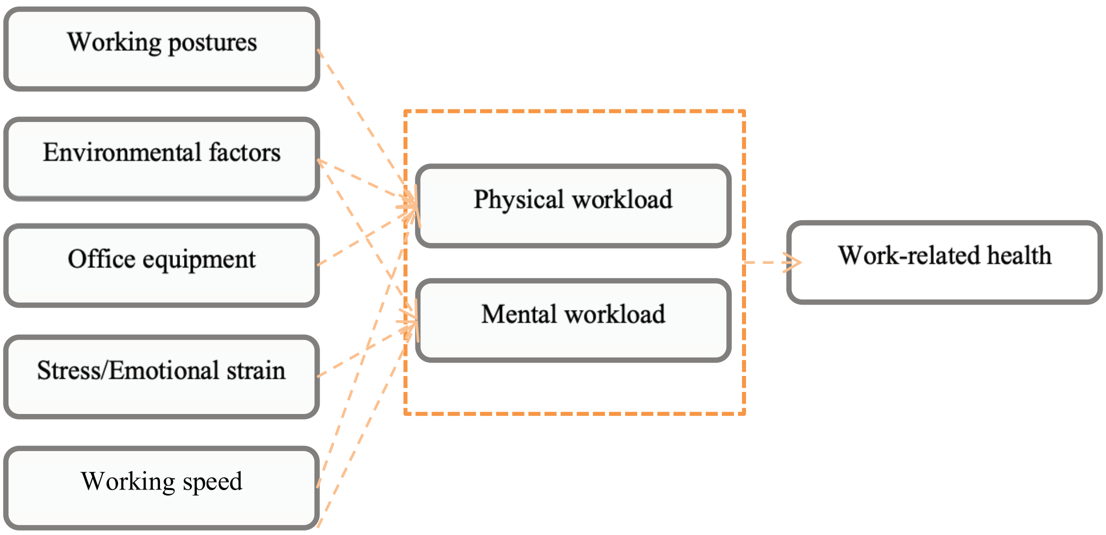

Figure 1. Some factors affecting the work-related health of office workers.

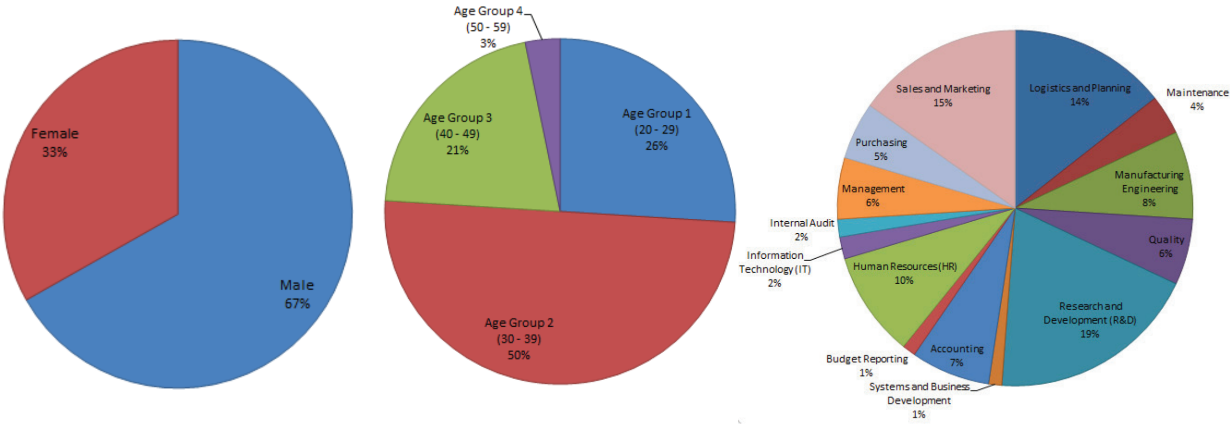

Figure 2. Distribution of participants by gender, age and departments.

Table 1. Departments of the participants

Department		Number of participants	Percentage (%)
Manufacturing	Logistics and planning	36	14.4
	Maintenance	9	3.6
	Manufacturing engineering	20	8.0
	Quality	15	6.0
	Research and development (R&D)	48	19.2
	Systems and business development	3	1.2
Administrative	Accounting	18	7.2
	Budget reporting	3	1.2
	Human resources (HR)	24	9.6
	Information technology (IT)	5	2.0
	Internal audit	4	1.6
	Management	14	5.6
	Purchasing	13	5.2
	Sales and marketing	38	15.2
Total		250	100

33.5% are women. The average experience at work is 9.7 (± 6.4) years. The distribution of the participants by gender, age and departments are visualised in Figure 2. The numbers of participants on the basis of departments are also given in Table 1.

Rapid Office Strain Assessment (ROSA)

ROSA is an observational assessment method designed to quickly measure ergonomic risks associated with computer work and to create an action level according to the level of discomfort of office workers [20]. While an observer makes an assessment with the ROSA method, he/she chooses the figures indicated in the ROSA form in accordance with his/her observations and scores accordingly. In scoring, the time spent by the office worker using the equipment and the adjustability of the relevant equipment's features such as height and depth is also taken into account.

The ROSA form has three sections:

(1) Section A (Chair): Scores for the height and depth of the seating surface are determined. Then the armrest and back support score is determined with the help of the figures on the form. By placing these two scores in an intersection matrix, a chair total score is calculated.

(2) Section B (Monitor and Telephone): Scores for the monitor height and working hours on the monitor are first determined. Then, scores are determined for the position of the neck when using the phone and the working hours on the phone. The total score for the monitor and telephone section is calculated by placing these two scores in an intersection matrix.

(3) Section C (Keyboard and Mouse): A score is determined taking into account the hand, arm and shoulder postures and working hours when using the mouse. Then a similar score is determined for the keyboard. The total score for the keyboard and mouse section is calculated by placing these two scores in an intersection matrix.

After scoring the chair, monitor, telephone, keyboard and mouse, the final risk score is determined between 1 and 10 through an interaction matrix. In this matrix, the chair section score is used as the vertical axis and a value obtained from the other two sections is used as the horizontal axis [20]. According to the ROSA final score, there are four ergonomic risk levels:
(1) Low risk level: Score 1 - 2
(2) Moderate risk level: Score 3 - 4
(3) High risk level: Score 5 - 7
(4) Very high risk level: Score 8 - 10 [21].

Cornell Musculoskeletal Discomfort Questionnaire (CMDQ)

CMDQ is one of the most common methods for assessing the risk level of MSDs of employees. This questionnaire was developed by Hedge et al. in 1999 in the Human Factors and Ergonomics Laboratory at Cornell University [22,23]. The validity of this method was extensively tested and yielded good results [24]. The CMDQ can be applied to sedentary and standing employees; it has different versions for males and females.

In the CMDQ form, the frequency, the severity and the work interference of the musculoskeletal pain are scored for 18 different body regions. It also includes a figure showing the relevant body regions to help visually. The responses are given considering the last working week. Frequency, severity and work interference scores can be used as percentages or given weights. Frequency score is rated across 'never', '1-2 times a week', '3-4 times a week', 'once a day' and 'several times a day' with weights of 0, 1.5, 3.5, 5 and 10 respectively. The severity score is rated across 'slightly uncomfortable', 'moderately uncomfortable' and 'very uncomfortable' with weights of 1, 2 and 3 respectively. The work interference score is rated across 'not at all', 'slightly interfered' and 'substantially interfered' with weights of 1, 2 and 3 respectively [24].

The CMDQ scores of each body region can be analyzed in four ways:
(1) by simply counting the number of symptoms per person
(2) by summing the rating values for each person
(3) by weighting the rating scores to more easily identify the most serious problems
(4) by multiplying the frequency score by the severity score and work interference scores

The final discomfort score can be classified as 'slightly', 'moderately' and 'very uncomfortable' [22].

The participants in this study completed the Turkish version of the CMDQ.

Nasa Task Load Index (NASA-TLX)

NASA-TLX is a subjective mental workload assessment method that was designed by Hart and Staveland in 1988 [25]. A workload score of ratings on six factors is obtained with NASA-TLX. These six factors and their explanations are as follows:
(1) Mental demand: How much thought, decision or calculation do you need to accomplish the task?
(2) Physical demand: How much intensity of physical activity do you need to complete the task?
(3) Temporal demand: How much time pressure do you feel about completing the task?
(4) Performance: How hard do you have to work to maintain your level of performance?
(5) Effort: what is your success level in completing the task?
(6) Frustration: How insecure or discouraged do you feel during the task?

The NASA-TLX method consists of three stages: scaling, weighting and determining the overall workload. The effect of six sub-factors on the job in the scaling phase is determined by marking the scale created between "very low" and "very high". In the weighting stage, each participant weighs six factors in proportion to their contribution to the workload. Pairwise Technique (PWT), known as the pairwise comparison technique, is used to reveal the weights. In this technique, 15 comparisons are made between six sub-factors, including two in terms of importance level within the scope of work. Participants mark the criterion they think contributes the most to the workload during paired comparisons. Thus, the frequency value of each criterion is obtained. Then, the value for the sub-factor is divided by 15 and the weight value for that factor is obtained. In the last stage, the general workload index is obtained by multiplying the ratio results with the weight value of each criterion and adding them together [26]. The participants completed a NASA-TLX form scaled from 1 to 20, taking their daily office tasks into account.

RESULTS AND DISCUSSION

Statistical analyses were carried out using Minitab version 18. All data conformed to normal distribution. A one-way variance analysis for equality of means was conducted to determine whether there were significant differences between the risk scores of the departments. Tukey multiple comparison test (post-hoc test) was used for finding the different departments. The confidence level is 95% in all analyses.

Office workers were observed while applying the analysis methods. Some examples of sitting positions and hand-wrist postures encountered in the offices are given in Figure 3.

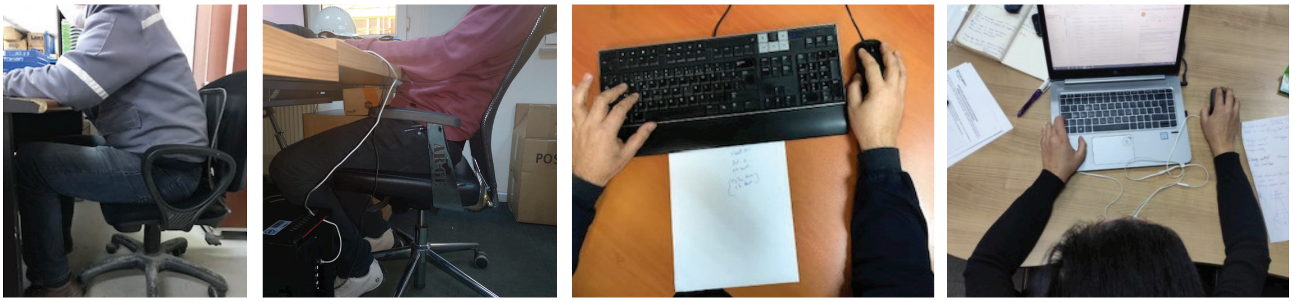

Figure 3. Examples of working postures in the workplace.

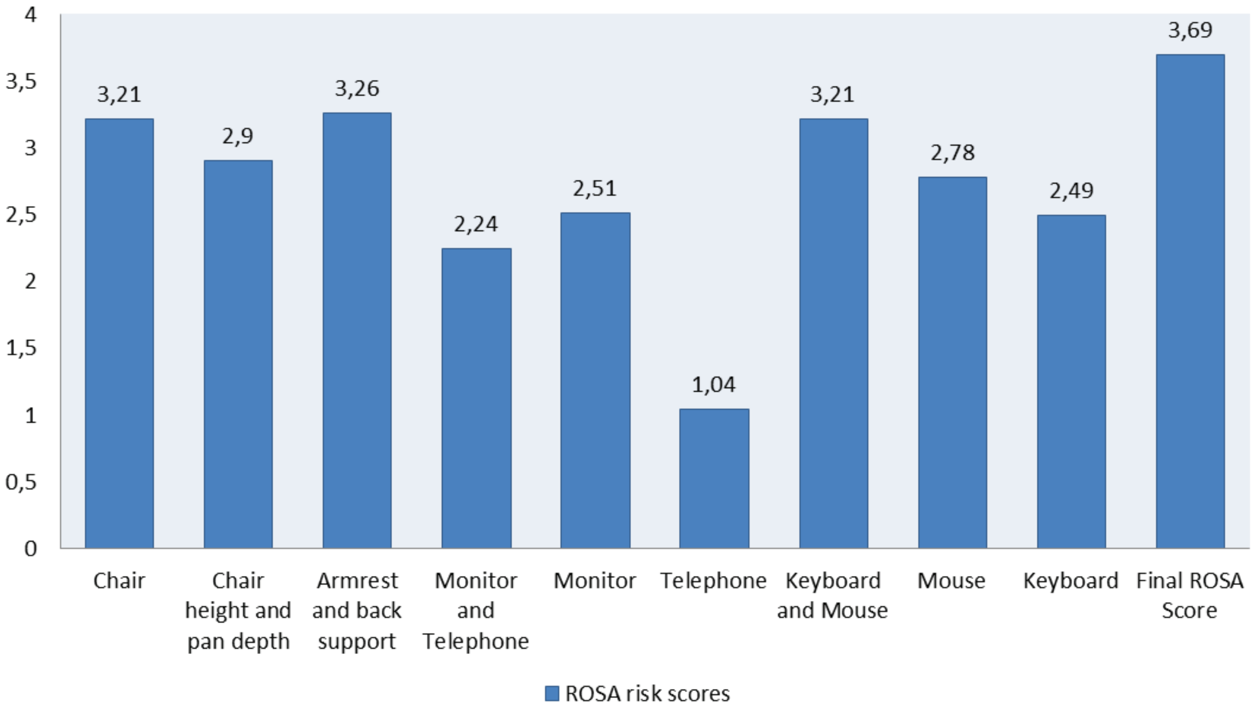

Figure 4. The ROSA risk scores.

Results of ROSA Method

The risk scores for ROSA sub-sections and the final ROSA scores of the participants are summarized in Figure 4. The average of the final ROSA score is 3.69 which correspond to a moderate risk level. The chair section score is 3.21 and the keyboard and mouse section score is 3.21. The monitor and telephone section score is the lowest with 2.24 points.

Considering that moderate and above risk levels should be taken into account, the number of ROSA sub-scores for chair, monitor and telephone, keyboard and mouse sections with risk scores of 3 and above were determined and given in Table 2. It is observed that approximately 62% of the employees are at moderate and above risk levels for the chair, 29% for the monitor and telephone and 64% for the keyboard and mouse. According to the final ROSA score,

Table 2. The numbers with moderate, high and very high levels of risk for ROSA sub-sections

Section	Number	%
Chair	156	62.4
Chair height and pan depth	121	48.4
Armrest and back support	148	59.2
Monitor and telephone	72	28.8
Monitor	96	38.4
Telephone	23	9.2
Keyboard and mouse	161	64.4
Mouse	143	57.2
Keyboard	121	48.4
Final ROSA score	209	83.6

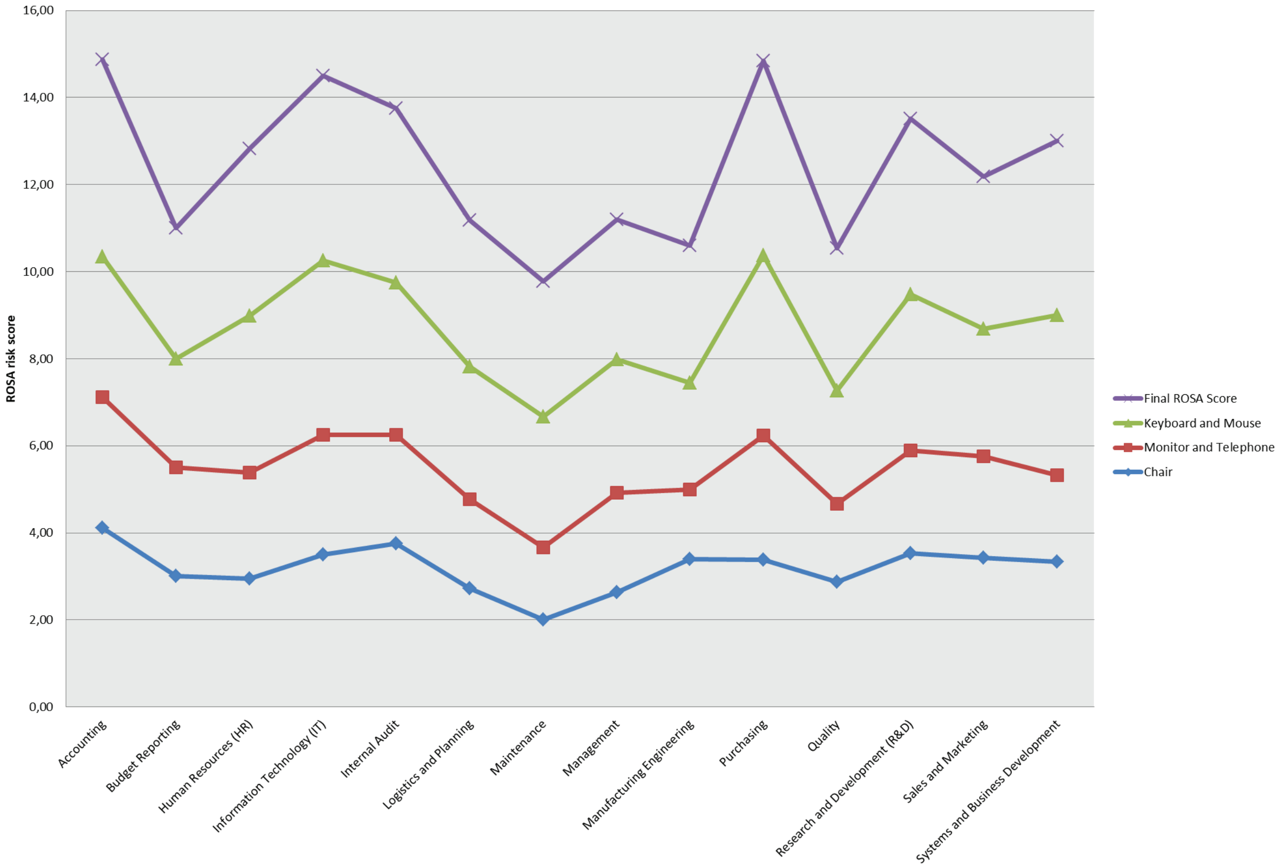

Figure 5. The average ROSA scores of the departments.

83.6% of the participants are at moderate and above risk levels.

Office workers in this workplace have particular problems with chair height. Almost half of the employees stated that the height and pan depth of their chairs are not suitable. The weight of the score in the monitor and telephone sub-section mostly comes from the monitor scores. Approximately 38% of office workers stated moderate or higher discomfort with the monitor. The numbers of moderate or higher risk scores in the mouse and keyboard sub-sections are also considerably high. Approximately 57% of employees stated that they had moderate or higher level problems with the use of the mouse.

The average ROSA scores according to the departments are seen in Figure 5. According to the final ROSA scores, the highest risk is seen in Accounting, Purchasing and IT departments. Besides, the department with the most discomfort with the chair is the Accounting department. Accounting is also the department that has the most discomfort with the use of monitors and phones. And in Purchasing and IT departments, it is seen that the use of the keyboard and mouse causes the most discomfort.

Results of CMDQ method

The discomfort scores for each body region obtained with the responses of all participants to the CMDQ questionnaire are given in Table 3. Discomfort in the neck region has the highest proportion of 15.89%. The upper back has a proportion of 11.81%, the lower back has a proportion of 10.85% and the right wrist has a proportion of 10.82% which are the next highest scores. The scores of the right and left shoulders are also considerably higher.

The risk levels of the participants were classified according to the risk scores for the neck, shoulders, upper back, lower back and wrists. The number and percentages of employees classified by CMDQ risk score for these body regions are given in Table 4. For the neck region, 12.8% of the employees have moderate risk levels, 9.2% of them have high risk levels and 2% of them have very high risk levels. Considering the moderate, high and very high risk levels, it is seen that almost 20% of the employees are working at these risk levels for most of the body regions.

The average discomfort scores of the neck, shoulders, upper back, lower back and wrists which are the

Table 3. The CMDQ discomfort scores

Body region		Score	%
Neck		1390.5	**15.89**
Shoulder	Right	716.0	8.18
	Left	769.0	8.79
Upper back		1033.0	**11.81**
Upper arm	Right	151.0	1.73
	Left	229.0	2.62
Lower back		949.5	**10.85**
Forearm	Right	199.0	2.27
	Left	251.0	2.87
Wrist	Right	946.5	**10.82**
	Left	514.5	5.88
Hip		260.0	2.97
Thigh	Right	134.5	1.54
	Left	137.0	1.57
Knee	Right	247.0	2.82
	Left	471.5	5.39
Lower leg	Right	122.5	1.40
	Left	227.5	2.60
Total CMDQ score		8749.0	100

body regions that have the most proportions of the discomfort, are presented in Table 5 according to departments. Discomfort in the neck region mostly occurred in IT, Systems and Business Development and Sales and Marketing departments. Discomfort in the shoulders and wrists mostly occurred in the IT and Systems and Business Development departments. Upper back discomfort is also common in the IT department, while lower back discomfort is common in Purchasing.

Significant differences in average risk scores between departments were found by applying one-way ANOVA ($p<0.05$). Post-hoc tests were conducted to find out which departments are significantly different. The variance homogeneity was checked before the post-hoc test selection. Since the variances were found to be homogeneous, the Tukey post-hoc test was applied. According to the results of the Tukey test, it was determined that IT, Sales and Marketing and Systems and Business Development departments made the difference. The boxplot of data and normal probability plot of residuals are given in Figure 6.

Table 4. The number of participants classified by CMDQ risk levels for the riskiest regions

Risk level	Neck	Right shoulder	Left shoulder	Upper back	Lower back	Right wrist	Left wrist
0 = no risk (0 score)	123 (49.2%)	182 (72.8%)	181 (72.4%)	158 (63.2%)	168 (67.2%)	175 (70.0%)	207 (82.8%)
1 = low (1.5 - 4.5 score)	67 (26.8%)	36 (14.4%)	37 (14.8%)	48 (19.2%)	40 (16.0%)	36 (14.4%)	24 (9.6%)
2 = moderate (5 - 14 score)	32 (12.8%)	20 (8.0%)	14 (5.6%)	24 (9.6%)	23 (9.2%)	21 (8.4%)	9 (3.6%)
3 = high (15 - 45 score)	23 (9.2%)	8 (3.2%)	14 (5.6%)	15 (6.0%)	16 (6.4%)	11 (4.4%)	5 (2.0%)
4 = very high (60 - 90 score)	5 (2.0%)	3 (1.2%)	3 (1.2%)	5 (2.0%)	3 (1.2%)	5 (2.0%)	3 (1.2%)

Table 5. The average CMDQ discomfort scores according to departments

Department	Neck	Right shoulder	Left shoulder	Upper back	Lower back	Right wrist	Left wrist
Accounting	7.08	3.08	4.11	7.00	5.11	4.03	1.67
Budget reporting	1.67	1.67	1.67	1.50	0.50	0.00	0.00
Human resources	8.52	4.33	4.67	5.63	1.29	3.10	2.81
Information technology (IT)	**19.70**	13.40	12.00	**14.10**	2.20	8.70	8.30
Internal audit	2.25	0.00	0.38	0.75	0.00	0.00	0.00
Logistics	5.19	1.15	1.36	2.42	4.28	2.15	0.49
Maintenance	5.72	0.00	1.11	1.28	1.11	4.22	0.17
Management	3.46	2.07	0.36	0.11	0.00	1.11	0.00
Manufacturing	1.80	0.38	3.20	1.03	1.63	1.80	0.48
Purchasing	4.96	2.19	2.81	2.88	**9.62**	3.85	2.96
Quality	3.83	5.10	0.23	3.33	1.33	0.97	0.23
Research and development (R&D)	3.24	0.76	0.57	2.88	2.80	4.00	0.66
Sales and marketing	8.38	5.57	7.04	8.41	8.74	7.96	5.62
Systems and business development	9.00	**17.83**	**17.83**	9.50	2.00	**10.00**	**20.00**

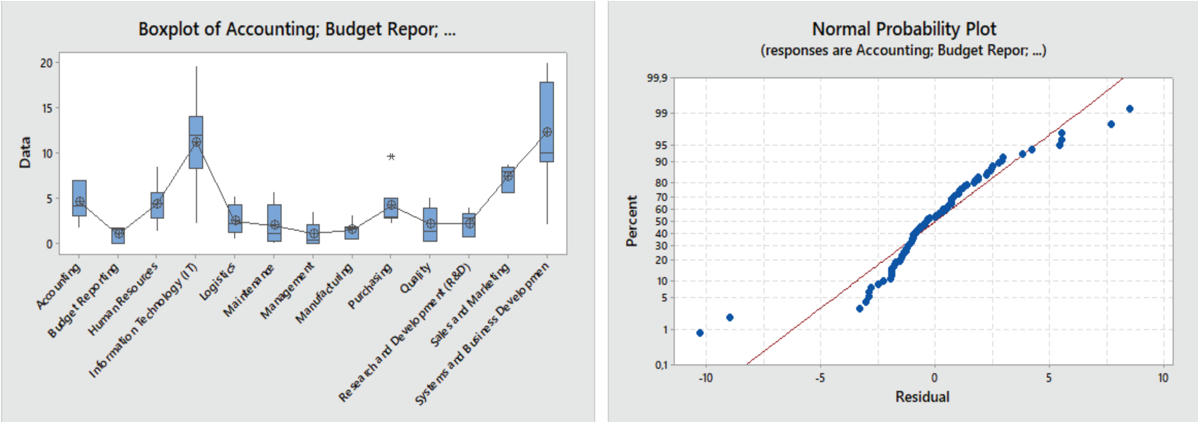

Figure 6. Tukey test results for departments.

Results of the NASA-TLX method

In the NASA-TLX application, the participants first made a scale between 0 and 20 for each sub-factor. The NASA-TLX sub-factor scores of the participants are summarized in Table 6. Effort, mental and temporal demand factors were scaled higher. In paired sub-factor comparisons, since there was no different opinion from the participants it was assumed that all sub-factors are equally weighted with each other. Accordingly, the TLX values calculated in the range of 0-100 and the average TLX scores of the departments are seen in Figure 7. The departments with the highest mental workload are Accounting, Maintenance and Purchasing.

Table 6. The scores for NASA-TLX sub-factors

Factor	Mean	St.Dev.	Minimum	Maximum
Mental demand	14.487	3.882	1	20
Physical demand	7.694	4.241	0	19
Temporal demand	13.875	4.320	1	20
Performance	4.728	3.489	1	18
Effort	15.487	3.851	1	20
Frustration	10.737	5.257	1	20
NASA-TLX score	55.841	11.955	20	85

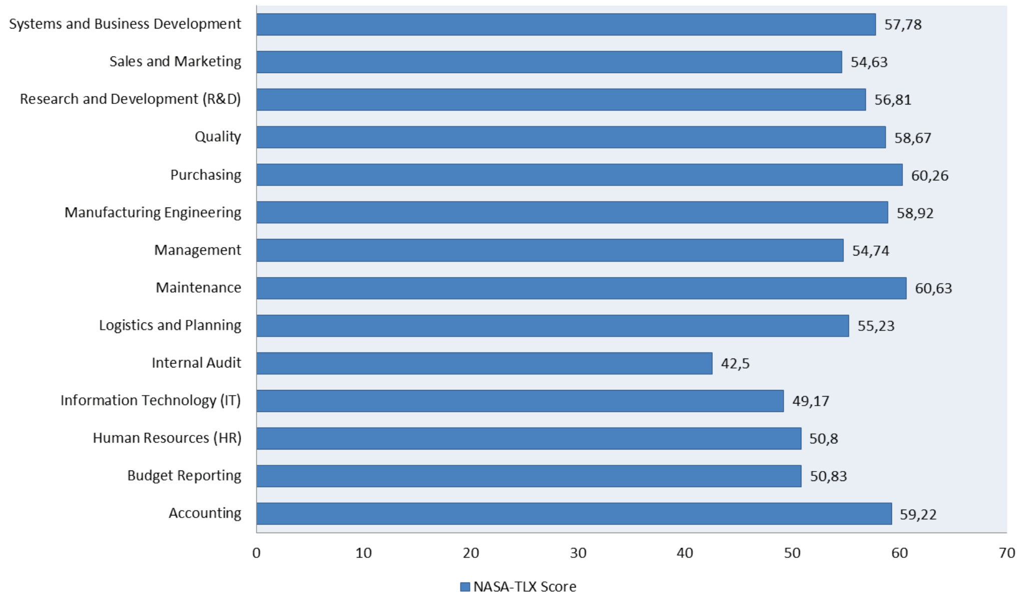

Figure 7. The average NASA-TLX scores of the departments.

Correlations between CMDQ and ROSA scores

A correlation analysis was performed to determine whether the discomfort reported by the participants in the CMDQ was related to the ROSA risk scores. The correlations between ROSA final score and CMDQ scores are given in Table 7. As seen in the table, the discomforts in the neck (r=0.239), shoulders (r=0.172 and 0.156 respectively), upper back (r=0.206), right forearm (r=0.218), wrists (r=0.247 and 0.144 respectively) and right lower leg (r=0.185) with p-values less than 0.05, are positively correlated with the final ROSA scores. The total CMDQ score and ROSA final score are also positively correlated with r=0.257 Pearson correlation coefficient. These correlations are significant at a 95% confidence level.

Correlations between NASA-TLX and ROSA/CMDQ scores

Another correlation analysis was performed to determine if the mental workload values of the employees were related to the ROSA risk scores. The correlations between ROSA final score and NASA-TLX scores are given in Table 8. As seen in the table, the performance (r=0.172) and frustration (r=0.136) sub-factors with p-values less than 0.05 are positively correlated with ROSA final score. There is also a significant correlation between ROSA and NASA-TLX scores (r=0.162).

The possible correlation between NASA-TLX and CMDQ results was also analyzed. No significant correlation was found between NASA-TLX and CMDQ scores. Although significant correlations were found between some NASA-TLX sub-factors and some CMDQ body regions, the correlation coefficients were very low.

Table 7. The correlations between ROSA final score and CMDQ scores

Body regions		Pearson correlation (r)	p
Neck		**0.239**	**0**
Shoulder	Right	**0.172**	**0.013**
	Left	**0.156**	**0.024**
Upper back		**0.206**	**0.002**
Upper arm	Right	0.120	0.104
	Left	0.059	0.420
Lower back		0.104	0.138
Forearm	Right	**0.218**	**0.003**
	Left	0.083	0.255
Wrist	Right	**0.247**	**0**
	Left	**0.144**	**0.044**
Hip		0.125	0.089
Thigh	Right	0.101	0.168
	Left	0.08	0.277
Knee	Right	0.045	0.535
	Left	-0.001	0.989
Lower leg	Right	**0.185**	**0.012**
	Left	0.111	0.131
Total CMDQ score		**0.257**	**0**

Table 8. The correlations between NASA-TLX scores and ROSA final score

NASA-TLX sub-factors	Pearson correlation (r)	p
Mental demand	0.085	0.195
Physical demand	0.002	0.970
Temporal demand	0.119	0.070
Performance	**0.172**	**0.009**
Effort	0.039	0.553
Frustration	**0.136**	**0.038**
NASA-TLX score	**0.162**	**0.014**

The Relationship Between Gender and Age With Risk Scores

One-way ANOVA was performed to understand whether the risk scores and discomfort levels obtained by the three methods differ according to gender and age factors.

It was observed that the gender factor affected the ROSA final scores. The average ROSA final score for males is 3.48 and it is 4.08 for females. The difference between them was significant with a p-value of 0.001 for a 95% confidence level. The gender factor had also an effect on the CMDQ scores. The average CMDQ score for males is 22.60 and it is 59.90 for females. The difference between them was significant with a p-value of 0. There was no change by gender in NASA-TLX scores.

The age ranges of the participants were divided into 4 groups (20-29, 30-39, 40-49, 50-59) and the effect of age on risk scores was examined. Although the averages of risk scores were higher for employees in the 30-39 age range, the differences between age groups were not statistically significant.

The average ROSA final risk score was 3.69 and the percentage of office workers who need intervention was 83.6%. Similarly, ROSA final score was 2.25 and the higher risk level percentage was 71% in a study conducted in the offices of a communication service company [27]. In a study examining different types of offices, the final ROSA score was found to be 3.61 [28]. The average ROSA score of different offices in the manufacturing sector was found to be 3.52 which also correspond to a moderate risk level [9]. Furthermore, when MSD risk levels were analyzed on the basis of departments, it was found to be high in the Accounting department, similar to the literature [9].

The discomfort scores calculated by the CMDQ responses for the neck, upper back, lower back and right wrist had the highest proportion. Left and right shoulders had also considerably higher discomfort scores. The body regions where the most discomfort was reported, matched up with some other results in the literature [4, 9, 12, 13, 28]. Most likely causes of discomfort for the neck, shoulders and upper back are unsuitable chairs, lack of back support and inappropriate seating positions. The height of the chairs should be adjustable according to the monitor or table and correct sitting positions should be learned and applied. The discomfort in the right wrist can be directly related to the size of the mouse and the lack of wrist support.

It was observed that there is a significant relationship between the neck and right wrist disorders specified in CMDQ and the ROSA final scores. This is an expected result; because discomfort related to chairs, monitors and mouse which are questioned in ROSA can be seen in the neck, back, shoulders, arms and legs. According to the ROSA scores, monitor heights are not suitable for most employees. Neck discomfort can occur when the monitor height is not suitable for the height of the employee. This correlation result is consistent with the studies in the literature [29, 30, 31].

Most of the employees in this study are right-handed. Therefore, it was determined that there is discomfort in the right wrist related to the use of the mouse. Inappropriate mouse size and long working hours without any breaks may cause this discomfort. In the offices where this study is carried out, some employees do not use a mousepad or any wrist support while working with the mouse. This may cause MSDs such as carpal tunnel syndrome which happens because of excess pressure on the median nerve that goes through the wrist. Providing appropriate wrist support for office workers will be sufficient to solve this problem. The results and suggestions were presented to the company, and suitable mouse and mousepads were provided by the company for office workers.

Some of the office workers in the company use desktop PCs and monitors, and some use laptops. A few of them use laptops with height-adjustable stands and an external keyboard. The workers who do not use external keyboards work by keeping their wrists in the wrong position (away from a neutral posture). By keeping the wrists as close to the neutral position as possible, discomfort and MSDs can be prevented.

The mental workload values calculated by six factors of the NASA-TLX method showed that the departments with the highest mental workload were Accounting, Maintenance and Purchasing departments. A higher mental workload is expected especially in tasks that require high responsibility. Mental demand, temporal demand and effort sub-factors were scaled higher than other sub-factors. Since thinking, decision making and calculation processes are in the majority in the mentioned departments and there is usually time pressure, it is an expected result that the sub-factors associated with these situations (especially mental and temporal demand) are scored high.

Some studies find a correlation between mental workload and MSD risk levels [12, 15, 17, 18]. In this study, participants expressed physical discomfort that may pose a risk of MSD and also expressed mental workload, especially in some departments. Due to the low correlation coefficient between NASA-TLX and ROSA scores, it can be said that the strength of the relationship between physical and mental workload is weak. Even though the employees experience some physical discomfort, most employees do not see it as a mental burden. Employees often have to complete their jobs with deadlines and work with maximum performance. They may not think that their mental workload is too high because their performance must be high. While office workers evaluate time pressure and performance factors higher, people with different individual characteristics may feel the mental workload differently [19].

When the difference between female and male employees was considered, it was concluded that the ROSA final scores were higher for female participants. In a study using a questionnaire method, it was found that women reported more discomfort, especially in the shoulder, neck and upper back regions [4]. In this study, a similar result of gender difference was found in both methods (ROSA and CMDQ) examining physical load and MSD risks. In addition, the riskiest body regions found by the questionnaire method also overlap with the study in the literature.

CONCLUSION

In this study, CMDQ, ROSA and NASA-TLX methods were used to analyze MSD risks and mental workload among office workers in an automotive supplier company. The CMDQ was applied to determine the MSD levels of workers. The ROSA method was used to obtain risk scores associated with office furniture and equipment. Finally, the NASA-TLX method was applied to reveal the mental workload levels. Data were collected from a total of 250 office workers from different departments in an automotive spare part manufacturing company.

Statistical analyses with a confidence level of 95% were performed for the determination of MSDs risk and mental workload levels. Evaluations were made on the basis of departments. The average of the ROSA final scores was 3.69. That means most of the employees were at moderate and higher risk levels. Considering the chairs 62% of the employees were at moderate and above risk levels. Similar risk level percentages were 64% for the keyboard and mouse, and 29% for the monitor and telephone. CMDQ results showed the neck, upper back, lower back and right wrist were the body regions where the office workers experienced more discomfort. The Sales and Marketing, Information Technology and Systems and Business Development departments were the departments where the most physical discomfort was expressed for these body regions. As to TLX scores, the highest mental workload was identified in Accounting, Maintenance and Purchasing departments.

There was a positive and significant correlation between ROSA final scores and CMDQ risk levels for the neck and right wrist regions. Besides, a relationship between ROSA and TLX scores was found. Some correlations, albeit weak, between some body regions and NASA-TLX sub-factors were also found. There was a significant difference between the ROSA final scores of female and male participants, female workers reported higher levels of discomfort. The effect of the age group of the employees was also examined, but the effect of age on discomfort levels or mental workload was found to be insignificant.

Considering the results of the study, some suggestions were made to the company. One of them was the use of an appropriate-sized mouse and mousepad to prevent discomfort in the wrists. The company supplied mouse and wrist supports and employees started to use them. In addition, a training seminar about office ergonomics was given to the employees. Employees were informed that wrists should be in a neutral position when using a laptop or an external keyboard. Correct sitting positions were also mentioned in terms of legs, upper back and lower back health. Using appropriate office equipment and learning the correct working positions will be essential to prevent any discomfort or MSDs in office workplaces.

AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

REFERENCES

[1] Kar G, Hedge A. Effects of a sit-stand-walk intervention on musculoskeletal discomfort, productivity, and perceived physical and mental fatigue, for computer-based work. Int J Ind Ergon 2020;78:102983. [CrossRef]

[2] Silverstein B, Evanoff B. Musculoskeletal Disorders. In: Levy BS, Wegman DH, Baron SL et al (ed) Occupational and environmental health: recognizing and preventing disease and injury. Oxford University Press, New York, 2011. p. 335-365.

[3] Straker L, Abbott RA, Heiden M, Mathiassen SE, Toomingas A. Sit-stand desks in call centres: Associations of use and ergonomics awareness with sedentary behavior. Appl Ergon 2013;44:517−522. [CrossRef]

[4] Cho CY, Hwang YS, Cherng RJ. Musculoskeletal symptoms and associated risk factors among office workers with high workload computer use. J Manipulative Physiol Ther 2012;35:534−540. [CrossRef]

[5] James C, James D, Nie V, Schumacher T, Guest M, Tessier J, Marley J, et al. Musculoskeletal discomfort and use of computers in the university environment. Appl Ergon 2018;69:128−135. [CrossRef]

[6] Wærsted M, Hanvold TN, Veiersted KB. Computer work and musculoskeletal disorders of the neck and upper extremity: a systematic review. BMC Musculoskelet Disord 2010;11:1−15. [CrossRef]

[7] Sohrabi M, Faridizad AM, Farasati F. Comparing results of musculoskeletal disorders evaluation in computer users with CMDQ, RULA and ROSA methods. J Ilam Uni Med Sci 2015;23:53−62.

[8] Kahya E. & Erkaplan F. Ergonomic risk assessment with ROSA and Cornell methods in the offices of a large-scale manufacturing enterprise. J Ind Eng 2022;33:469−483. [CrossRef]

[9] Kahya E. Assessment of musculoskeletal disorders among employees working office workplaces in the manufacturing sector. Work 2021;69:1103−1113. [CrossRef]

[10] Azma K, Nasiri I, Abedi M. The survey of musculoskeletal disorders risk factors among office workers and the implementation of an ergonomic training program. Mil Med 2015;16:211−216.

[11] Baker R, Coenen P, Howie E, Williamson A, Straker L. The musculoskeletal and cognitive effects of under-desk cycling compared to sitting for office workers. Appl Ergon 2019;79:76−85. [CrossRef]

[12] Darvishi E, Maleki A, Giahi O, Akbarzadeh A. Subjective mental workload and its correlation with musculoskeletal disorders in bank staff. J Manipulative Physiol Ther 2016;39:420−426. [CrossRef]

[13] Besharati A, Daneshmandi H, Zareh K, Fakherpour A, Zoaktafi M. Work-related musculoskeletal problems and associated factors among office workers. Int J Occup Saf 2020;26:632−638. [CrossRef]

[14] Nourollahi-Darabad M, Afshari D & Gomari AE. The relationship between lifestyle and mental workload with the prevalence of musculoskeletal discomfort: A case study in the automotive industry. J Occup Hyg Eng 2022;9:102−110. [CrossRef]

[15] Nino L, Marchak F, Claudio D. Physical and mental workload interactions in a sterile processing department. Int J Ind Ergon 2020;76:102902. [CrossRef]
[16] Wang X, Lavender SA, Sommerich CM, Rayo MF. Exploring the relationships between computer task characteristics, mental workload, and computer users' biomechanical responses. Ergonomics 2022;65:1256−1265. [CrossRef]
[17] Muhammad MS. The relationship between musculoskeletal disorders and mental workload among female computer workers at services sector in Shah Alam (doctoral dissertation). Malaysia: University of Malaya; 2021.
[18] Nino V, Claudio D & Monfort SM. Evaluating the effect of perceived mental workload on work body postures. Int J Ind Ergon 2023;93:103399. [CrossRef]
[19] Darvishi E, Ghasemi F, Sadeghi F, Abedi K, Rahmati S & Sadeghzade G. Risk assessment of the work-related musculoskeletal disorders based on individual characteristics using path analysis models. BMC Musculoskelet Disord 2022;23:616. [CrossRef]
[20] Sonne M, Villalta DL, Andrews DM. Development and evaluation of an office ergonomic risk checklist: ROSA-Rapid office strain assessment. Appl Ergon 2012;43:98−108. [CrossRef]
[21] Chaiklieng S, Krusun M. Health risk assessment and incidence of shoulder pain among office workers. Procedia Manuf 2015;3:4941−4947. [CrossRef]
[22] Cornell University Ergonomics Web. Cornell Musculoskeletal Discomfort Questionnaires (CMDQ). Available at: http://ergo.human.cornell.edu/ahmsquest.html. Accessed on Dec 10, 2021.
[23] Hedge A, Morimoto S, McCrobie D. Effects of keyboard tray geometry on upper body posture and comfort. Ergonomics 1999;42:1333−1349. [CrossRef]
[24] Erdinc O, Hot K, Ozkaya M. Turkish version of the Cornell Musculoskeletal Discomfort Questionnaire: Cross-cultural adaptation and validation. Work 2011;39:251−260. [CrossRef]
[25] Hart SG, Staveland LE. Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. Adv Psychol 1988;52:139−183. [CrossRef]
[26] Byers JC, Bittner Jr AC, Hill SG. Traditional and raw task load index (TLX) correlations: are paired comparisons necessary? Advances in Industrial Ergonomics and Safety I. Philadelphia: Taylor and Francis; 1989, p. 481−485.
[27] Haghshenas B, Habibi E, Haji Esmaeil Hajar F, Sartang AG, van Wijk L, Khakkar S. The association between musculoskeletal disorders with mental workload and occupational fatigue in the office staff of a communication service company in Tehran, Iran, in 2017. J Occup Health Epidemiol 2018;7:20−29. [CrossRef]
[28] Matos M, Arezes PM. Ergonomic evaluation of office workplaces with Rapid Office Strain Assessment (ROSA). Procedia Manuf 2015;3:4689−4694. [CrossRef]
[29] Ozkan NF, Kahya E. Assessing ergonomic risks in an university's administrative offices. J Fac Eng Archit Gazi Univ 2017;32:141−150. [CrossRef]
[30] Shariat A, Cleland JA, Danaee M et al. Relationships between Cornell Musculoskeletal Discomfort Questionnaire and online Rapid Office Strain Assessment questionnaire. Iran J Public Health 2018;47:1756.
[31] Vahdatpour B, Bozorgi M, Taheri MR. Investigating musculoskeletal discomforts and their relation to workplace ergonomic conditions among computer office workers at Alzahra Hospital, Isfahan, Iran. Phys Med Rehabilit Electrodiagn 2019;1:52−58.