Conference Paper

Analysis of Ergonomic Factors Related to the Indoor Health Comfort and Musculoskeletal Symptoms of Office Workers

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Abstract

The objective of this research was to investigate the following ergonomic factors that might be related to the indoor health and comfort (IHC) of office workers, such as sick building syndrome (SBS) symptoms, job comfort and musculoskeletal symptoms (MSS). The study sample comprised all 65 office workers who use computers/laptops. The methods and instruments used in the study include observation, interviews, work environment measurement and questionnaires that address job comfort as well as SBS and MSS complaints. The study results show that 53.85 percent of the workers had high levels of comfort and that 53.85 percent had SBS complaints, 33.85 percent of which were eye-strain complaints and 33.85 percent of which were complaints of fatigue. Moreover, 78.57 percent of the workers experienced MSS. The ergonomic factors that were not in compliance with established regulations or standards were chair dimension, desk dimension, computers, work posture, room dimension, room layout, room colour and environmental factors such as noise, lighting, temperature, humidity, carbon dioxide, formaldehyde and volatile organic compound (VOCs). The study revealed a significant relationship between activity-level factors and work comfortability; additionally, VOCs concentration was a factor associated with SBS complaints. On the other hand, no significant relationship was found between ergonomic factors and MSS complaints.

Keywords: work environment, sick building syndrome, musculoskeletal symptoms, indoor health and comfort, office ergonomics

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Received: 15 May 2018
Accepted: 3 June 2018
Published: 19 June 2018

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the ICOHS 2017 Conference Committee.

1. Introduction

Healthy, safe and comfortable work conditions have been concerns of individuals since the beginning of the Industrial Revolution [1]. According to the World Health Organization (WHO; 1983), people spend most of their time indoors, such as at home or in the

office. Office workers, in particular, are vulnerable to many diseases that are associated with their jobs, the equipment they use and their work environments. Occupational diseases that may be experienced by these employees include sick building syndrome (SBS) [2] and musculoskeletal disorders (MSDs). It can be caused by contaminated air in the room [3] as a result of inadequate ventilation, building materials, exterior pollution, microbes, building materials/office equipment and other generally unknown causes. Some previous studies related to MSDs have suggested that most office workers tend to experience back pain that is usually influenced by the duration of sitting and by maintaining poor posture while working [4]. A safe, healthy and properly designed work environment should be taken into account so that employees can work comfortably and productively.

Based on a preliminary survey conducted in Office X, the researcher found that most employees were maintaining poor posture while working; some employees who worked on the second floor had complaints of visual impairment and often felt tired and/or sleepy while working. Since the air conditioning was not working properly, the air in the room was stuffy and congested; the indoor air quality in Office X is not measured and a risk analysis of MSS complaints has not yet been implemented. Moreover, an evaluation of the workers' SBS symptoms and the workers' perceptions of inconvenience have never been assessed.

This study aimed to investigate the SBS symptoms, work comfort (indoor health and comfort; IHC) and MSS complaints of office workers in Office X, as well as associated ergonomic factors (work equipment and occupational, room architecture and environmental factors). Office X has never completed any research related to IHC (work-related comfort and complaints of SBS symptoms) or to MSS complaints that might be associated with ergonomic factors. This study was therefore conducted to fill that research gap.

2. Methods

This research was a descriptive analysis that was conducted by collecting primary data via walk-through observation, questionnaires, interviews, and environmental measurements. A cross-sectional study design was used since all variables were examined at the same time. The sample was comprising all 65 office workers who use computers/laptops in the office.

This study used a questionnaire consisting of the following five sections: respondent's self-identity data, respondent's habits and circumstances, a work-comfort questionnaire, an SBS symptoms questionnaire and a Nordic Body Map (NBM) questionnaire. The information on environmental work factors was obtained by implementing a measurement using appropriate measuring instruments. The data on room, chair and table dimensions were obtained by using a carpenter meter, while the physical condition of the room (e.g., room layout and colour) was determined through direct observation. The data were then analysed using two analysis methods: univariate analysis and bivariate analysis, which were conducted with chi-square tests and SPSS software version 23.

3. Results

As seen in Table 1, the most common complaints of the employees affected by SBS at the time of measurement were as follows: eye strain (33.85%) and tiredness/sleepiness (approximately 33.85%). Those percentages are followed consecutively by aqueous deficient dry eye complaints or other eye irritations (15.38%), headache (12.31%), dry skin (9.23%) and other complaints.

Table 1: Frequency distribution of work comfortability level, SBS symptom complaints, MSS symptom complaints on office workers in Office X.

Parameter	N	%
Work comfortability		
High	35	53.85
Low	30	46.15
SBS symptom complaints		
No complaints	30	46.15
Complaints	35	53.85
MSS symptom complaints		
No complaints	12	21.43
Complaints	44	78.57

The results study obtained by comparing ergonomic factors with some established standards. Analysis of chair dimensions used standards All steel Sum Chair [9]. Analysis of desk dimensions, computers, work posture and room colour used work environment and office ergonomic standards (Regulation of the Minister of Health of the Republic of Indonesia Number 48 Year 2016 on Occupational Safety and Health Standards). While

analysis of room dimension and room layout used Regulation of the Minister of Public Works of the Republic of Indonesia Number 47 Year 2007 on Technical Guidelines for the Construction of State Buildings. The ergonomic factors which did not comply with the established standards included chair and desk dimensions, computers, work posture, room dimension, room layout and room colour.

A comparison of the environmental factors considered in this study with work environment and office ergonomic standards (Regulation of the Minister of Health of the Republic of Indonesia Number 48 (2016) on Occupational Safety and Health Standards) is presented in Table 2.

Table 2: Summary of environmental factors in Office X.

Parameters	Units	Standards *)	Measurement Results
Physical			
Noise	dBA	55–65	63.2–69.5
Lighting	Lux	300	96–386
Temperature	°C	23–26	23.8–26.9
Humidity	%	40–60	66–79
Air rate	m/s	0.15–0.50	0.2
EMF	mT	0.5	0.00063–0.00092
Chemical			
Carbon monoxide	ppm	10	0.136–3.44
Carbon dioxide	ppm	1000	1759.2–1897.8
Formaldehyde	ppm	0.1	0.077–0.15
VOCs	ppm	3	2.58–3.18
Respirable dust	ppm	0.15	0.092–0.102
Asbestos	ppm	0.1	0.0059–0.0088
Biology			
Microbiology Microorganism	colony	700	21
Fungi	colony	1000	59

Note: *)Regulation of the Minister of Health of the Republic of Indonesia Number 48 Year 2016 on Occupational Safety and Health Standards.

Bivariate analysis is performed only on variables that have varied (and not similar) values, because if one variable contains only one value variation, bivariate analysis cannot be done using an SPSS program, and the software cannot then determine the *p*-value, OR and CI 95 percent results. In this study, the factors that have similar values (one variation) are seat dimension, desk dimension, computers, work posture,

room colour, humidity, air rate, EMF, carbon monoxide, carbon dioxide, respirable dust, asbestos and microbiology (i.e., microorganisms and fungi). These factors therefore were not calculated via bivariate analysis.

Based on the statistical analysis, which implemented a chi-square test method, the relationships between ergonomic factors and work comfort, SBS symptom complaints and MSS complaints of office workers in Office X are shown in Table 3.

As seen in Table 3, work duration, room dimension, room layout, noise, lighting, temperature, formaldehyde and VOCs were not associated with the work comfort of office workers in Office X. On the other hand, the activity level variable (p = 0.000) was found to have a significant relationship with the work convenience of functional staff members in Office X. Based on an analysis of the activity-level relationship with work convenience, the researcher also found the value of OR = 1.021 and CI 95% = 0.371–2.804, indicating that the employees with activity levels consisting mainly of sitting (80% of all activities) have a risk of poor comfortability that is 1.021 times higher than employees whose jobs do not require them to sit for a majority of the workday. The risk of poor comfortability among employees whose activity levels involved 80 percent sitting was 0.371 to 2.804 times higher than employees with activity levels that were not 80 percent dominated by activities requiring them to sit.

As seen in Table 4, room dimension, room layout, noise, lighting, temperature, and formaldehyde were not correlated with SBS symptoms of the office workers in Office X. In contrast, with respect to the VOC variable (p = 0.030), there was a significant relationship between VOCs and SBS symptoms among functional staff and staff members in Office X during the year 2017. Based on the analysis of the relationship between VOCs and SBS symptoms, the OR = 1.375 and CI 95% = 0.388–4.867, indicating that employees who are exposed to VOCs at higher concentrations than the established standard have a risk of having SBS symptoms that is 1.375 times greater than employees who are exposed to VOCs at concentrations that are in compliance with the standard. The risk of SBS symptom occurrence among the employees who were exposed to VOCs of unacceptable concentrations were 0.388 to 4.867 times higher than that of the employees who were exposed to VOCs with acceptable concentrations.

As shown in Table 5, there was no correlation between duration of work or activity level and MSS symptoms of the office workers in Office X.

Table 3: Analysis of ergonomic factor and work comfortability of office workers in Office X in Year 2017.

Ergonomic Factors	Work Comfortibility				Total		P-Value	OR	CI 95%
	High		Low						
	n	%	N	%	n	%			
Duration of work									
No risk	15	60	10	40	25	100	0.282	1 1.5	(0.545–4.127)
Risk	20	50	20	50	40	100			
Activity Level									
No risk	13	54.2	11	45.8	24	100	0.000**	1 1.021	(0.371–2.804)
Risk	22	53.7	19	46.3	41	100			
Room dimension									
Appropriate	30	68.2	14	31.8	44	100	9.547	1 6.857	(2.091–22.490)
Not appropriate	5	23.8	16	76.2	21	100			
Room Layout									
Appropriate	30	68.2	14	31.8	44	100	9.547	1 6.857	(2.091–22.490)
Not appropriate	5	23.8	16	76.2	21	100			
Noise									
Appropriate	2	25	6	75	8	100	0.426*	1 0.356	(0.062–2.043)
Not appropriate	15	48.4	16	51.6	31	100			
Lighting									
Appropriate	5	83.3	1	16.7	6	100	0.068*	1 8.75	(0.912–83.949)
Not appropriate	12	36.4	21	63.6	33	100			
Temperature									
Appropriate	15	48.4	16	51.6	31	100	0.426*	1 2.813	(0.489–16.16)
Not appropriate	2	25	6	75	8	100			
Formaldehyde									
Appropriate	4	50	4	50	8	100	0.709*	1 1.385	(0.291–6.581)
Not appropriate	13	41.9	18	58.1	31	100			
VOCs									
Appropriate	5	23.8	16	76.2	21	100	5.602	1 0.156	(0.038–0.636)
Not appropriate	12	66.7	6	33.3	18	100			

Note: *: Fisher's Exact Test; **: There is a significant relationship between two variables.

Table 4: Analysis the relationship between ergonomic factor and SBS symptom complaints on office workers in Office X in Year 2017.

Ergonomic Factor	SBS Symptom Complaints				Total		P-Value	OR	CI 95%
	Not Present		Present						
	n	%	n	%	n	%			
Room Dimension									
Appropriate	19	43.2	25	56.8	44	100	0.185	1 0.691	(0.243–1.962)
Not appropriate	11	52.4	10	47.6	21	100			
Room Layout									
Appropriate	19	43.2	25	56.8	44	100	0.185	1 0.691	(0.243–1.962)
Not appropriate	11	52.4	10	47.6	21	100			
Noise									
Appropriate	5	62.5	3	37.5	8	100	0.451*	1 2.024	(0.410–9.990)
Not appropriate	14	45.2	17	54.8	31	100			
Lighting									
Appropriate	1	16.7	5	83.3	6	100	0.182*	1 0.167	(0.018–1.587)
Not appropriate	18	54.5	15	45.5	33	100			
Temperature									
Appropriate	14	45.2	17	54.8	31	100	0.451*	1 0.494	(0.100–2.439)
Not appropriate	5	62.5	3	37.5	8	100			
Formaldehyde									
Appropriate	4	50	4	50	8	100	1.00*	1 1.067	(0.225–5.049)
Not appropriate	15	48.4	16	51.6	31	100			
VOCs									
Appropriate	11	52.4	10	47.6	21	100	0.030**	1 1.375	(0.388–4.867)
Not appropriate	8	44.4	10	55.6	18	100			

Note: *: Fisher's Exact Test; **: There is a significant relationship between two variables.

4. Discussion

Chairs of employees used in office X consist of 4 types of seats with almost the same dimensions. The employee's chairs can only be adjusted to the height of the chair. Existing seats are not suitable to work with computers. Chair dimensions which did not comply with the standards, included the depth of the seat, seat width, the width of the backrest, the length of the armrest, the distance between the armrest. Depth of existing seat 48 cm while the standard 38.1 - 45.7 cm. With a holder too deep, almost all employees do not lean while working on a computer. Width of existing chairs 50

Table 5: Analysis of the relationship between ergonomic factor and symptom complaints on office workers in Office X.

Ergonomic Factor	MSS Complaints				Total		P-Value	OR	CI 95%
	Not present		Present						
	n	%	n	%	n	%			
Duration of work									
No risk	5	25	15	75	20	100	7.349	1 0.167	(0.049–0.568)
Risk	24	66.7	12	33.3	36	100			
Activity Level									
No risk	6	31.6	13	68.4	19	100	3.558	1 0.281	(0.087–0.908)
Risk	23	62.2	14	37.8	37	100			

cm and 52 cm while the standard 45.7 cm. With a wider seat can cause the distance between the armrests wider so that the arm position is not close to the body, it can cause the position of the hand when using the computer is not exactly straight ahead. The existing armrest length is 30 cm and 31 cm while the standard is 26.7 cm. With longer armrests can cause the work chair cannot be drawn closer to the desk when working with computers.

The desk employed consists of a model of two similar sizes. Desk dimensions did not comply with the standard included the width and height of the desk. The width of the existing desk is 62 cm and 72 cm while the recommendation is at least 90 cm. With a desk width that is less than standard indicates that the desk area of the employee is insufficient to store the required items while working and too narrow to work. The existing desk height is 73 cm while the recommendation is 58 - 68 cm if adjustable or 72 cm if not adjustable. Employee table height measured exceeds the standard, so it can affect the position of the employee arm when using the computer arm will tend to form an angle of less than 90^{o}.

The description of computer usage that is inconsistent with the recommendation of Regulation of the Minister of Health of the Republic of Indonesia Number 48 Year 2016, included the angle between the arms with upper arm less than 90^{o}, while using the mouse position of the elbow is not held by the armrest of the chair, the position of the wrist not straight when using the mouse. The use of computers that are not in accordance with the standards caused by dimensions of chairs and desks that are inadequate and not intended for computer used. In line with that, a number of awkward posture was experienced by the employees. Posture work using a good computer

recommendation Regulation of the Minister of Health of the Republic of Indonesia No. 48 Year 2016 can be seen in Figure 1.

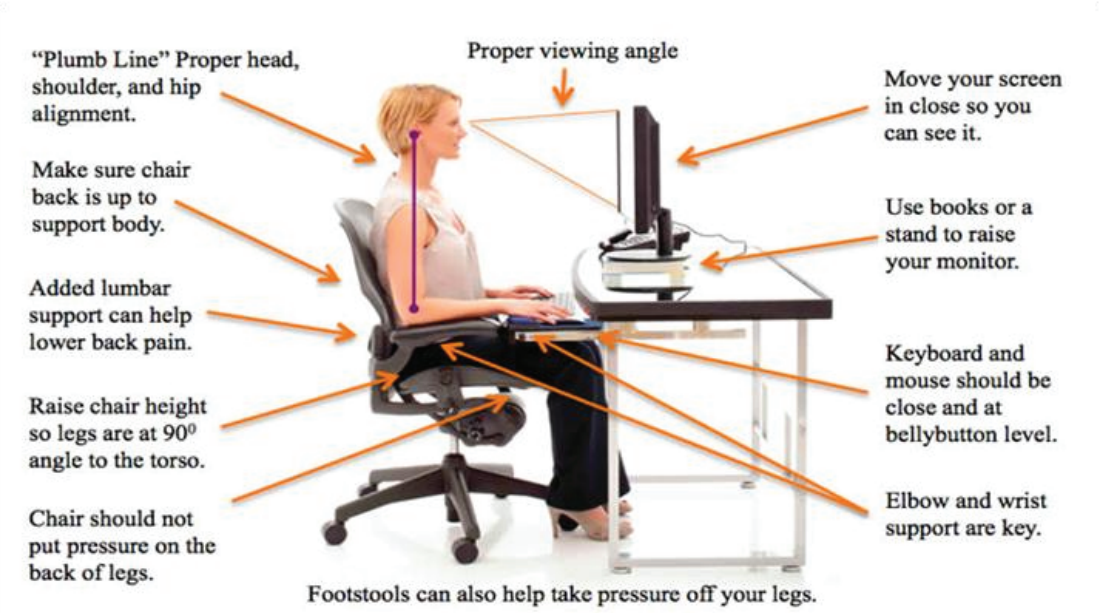

Figure 1: Ergonomic computer working position.

In addition to work posture, which is also associated with MSS complaints are the duration of work and activity level. About 61.54 percent of employees work in a sitting position/use the computer for > 4 hours. While employees who work with the dominant in a sitting position that is equal to 63.08 percent employees. The large number of employees who experience it because the type of work in office X is more dominant associated with office administration that requires a computer as a tool work.

The architecture factors of the room included room dimension, room layout, and colour of the room. Based on the standard workspace staff area is 2.2 m^2 and the plafond height of the floor is minimum 2.8 m. All work areas in Office X have met the minimum limit, but the table and chair equipment used is too large so that the employee space is limited. One of the five rooms observed has a plafond height below the standard of 2.63 m, and in that room used partition with high 1.5 m (over maximum high partition standards 1.37 m). That conditions made the occupants of the room difficult to communicate and uncomfortable while working. In terms of the colour of the room, the entire room in Office X using the wall colour is dim/dark and the lack of wall decoration so monotonous. It is not in accordance with the standards that recommend the colour of the walls is bright/cool and the addition of wall decoration so as not monotonous. Monotonous workspace conditions can result in eyestrain and low occupancy levels.

The environmental factors that did not meet the standards included noise, lighting, temperature, humidity, carbon dioxide, formaldehyde and VOCs. The noise value that exceeds the standard is due to the conversation of the employees while performing their duties, where activity in Office X is dynamic and continuous communication is needed. Noise exceeding 55 dB can disrupt and make others uncomfortable [1]. Almost all of the measured points have a lower luminance intensity value than the standard. The condition is due to the intensity of illumination of the lights are not great and not supported by light from the sun directly, because when working window/glass in the room covered with trellis. Lighting conditions that do not meet the standards can cause the eyes to become more contracted. Continually contracting eyes can cause tired eyes [8]. Temperature above the standard due to one of the AC is not operated. The use of split air conditioning makes the cooling uneven. Comfortable temperatures in clothing conditions are 20 - 26^{o}C [7]. High humidity can be caused by the occurrence of condensation due to improper ventilation. In Office X space used split AC and the entire room is closed to keep the air temperature, while no exhaust fan is available to drain out air. The concentration of carbon dioxide in the room is influenced by the activity of its users [1]. The concentration of carbon dioxide can be derived from human respiration. Almost all rooms in Office X are always in closed condition and very limited external air circulation. In addition, AC used is rarely cleaned and not maintained. For formaldehyde levels that exceed the standards caused by the many sources of formaldehyde gas producers such as the remaining floor cleaning soap, fernis/paint from the furniture in the room. In addition, the levels of VOCs in the room that exceeds the standard because of the room there are air freshener sufficient sting, in addition there is also odour perfume clothing from employees [10].

The questionnaire measurement results indicate that more than half the respondents have experienced SBS symptoms. Approximately 33.85 percent of the employees affected by SBS symptoms complained of tiredness and eye strain. The analysis revealed that the eye strain complaints potentially occurred due to inadequate lighting in Office X and to the generally monotonous colour of the room. On the other hand, the complaints of drowsiness probably arose from a high concentration of carbon dioxide in the room that causes a reduced oxygen supply to the brain, thus making employees tend to experience sleepiness.

Based on the NBM questionnaire, it can be seen that the percentage of respondents who have MSS complaints is 78.57 percent. These complaints, which are generally associated with pain in the neck, shoulders, upper back and lower back, are caused

mainly by the poor posture maintained by the worker [5], which is caused by inadequate chair and desk dimensions and the inappropriate use of computers/laptops.

In addition, inadequate lighting can also cause poor posture (bowed head). Similar to the effect of a dim light, glare also contributes to the occurrence of poor posture, since employees try to find a position from which to avoid the glare. The presence of MSS complaints is likely caused by the duration of a sitting position in front of the computer (sitting/working for > 4 hours or an activity level 80% dominated by sitting). Most office workers are likely to experience back pain, which often results from long periods of sitting and a poor sitting position [4].

Based on observations of the work postures of the employees, the researcher determined that most of the employees often had poor posture, such as legs bent inward, head down, raised heels, the body's failure to lean and bend, arms not leaning and bending and a view of the computer screen from a non-straight angle. Continued poor posture when working for long periods of time can cause MSD symptoms, such as back pain, neck pain, waist, numbness in the fingers and hand stiffness, weakness and pain while working at the computer [6].

The study findings indicate that 46.15 percent of the employees experience a low level of work comfortability and that 53.85 percent of employees experience a high level of work comfortability. Based on the environmental parameters, the condition of the work equipment and room layout generally do not meet the established standards. Since work comfortability is a variable that is influenced by user perceptions, the perceived comfort of work is not directly related to environmental parameters [7].

The ergonomic factors observed in the bivariate analysis on work convenience included job factors (work duration, activity level), the room's architectural factors (room dimension, room layout) and environmental factors (noise, lighting, temperature, formaldehyde and VOCs).

Based on the statistical analyses, the researcher determined that there is a relationship between the activity level and work convenience of office workers in Office X (p = 0.000). The OR value of 1.021 indicates that the employees whose activity levels are 80 percent dominated by sitting tend to have a risk of having a poor comfort level that is 1.02 times higher than that of the employees whose activity levels are not 80 percent dominated by sitting.

The duration of a sitting position can cause employees to easily feel bored and to experience visual discomfort due to the limited space and monotonous room conditions. In addition, employees who are required to stand for significant amounts of time also experience low levels of comfort.

Based on the statistical analyses, there is a relationship between VOC concentrations and SBS symptoms of office workers in Office X (p = 0.030). The OR value of 1.375 indicates that the employees who are exposed to high concentrations of VOCs tend to be 1.375 times more likely to experience SBS symptoms than those who are exposed to VOCs at concentrations that are in compliance with the established standard. The effects of exposure to VOCs are fatigue or sleepiness due to inadequate of oxygen supply to the brain, eye irritation, headache and lack of O_2 (due to asphyxiant VOCs).

Ergonomic factors observed in the bivariate analyses of MSS complaints are occupational factors that consist of work-duration and activity-level factors. Based on statistical analyses conducted on both variables, there is no relationship between work duration or activity level and MSS complaints of office workers in Office X. This finding is not in line with a study [8] which found that the conditions of static work can lead to acute pain and muscle fatigue.

5. Conclusions

Approximately 53.85 percent of the employees observed experienced SBS symptoms; the most common complaints were eye strain (33.85%) and fatigue, or sleepiness (33.85%). The percentage of employees with MSS complaints was 78.57 percent. In addition, 46.15 percent of the employees had perceived low levels of work convenience, and 53.85 percent had high levels of comfort.

The ergonomic factors which did not comply with the established standards included chair and desk dimensions, computers, work posture, room dimension, room layout and room colour. The environmental factors that did not meet the standards included noise, lighting, temperature, humidity, carbon dioxide, formaldehyde and VOCs. The ergonomic factor that most significantly contributed to SBS symptoms was the VOC concentration. However, there was no significant relationship between job factors (work duration and activity level) and the MSS complaints of office workers in Office X.

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