

that the objective of work system design is to optimize the whole system rather than maximize just one component [1]. People should be the central focus and the other factors should be designed to help the person work effectively and comfortably.

Research studies showed that many cases of shoulder and neck pain were caused by inappropriate design or use of furniture [4]. Users should position their heads so that minimum stress is put on the neck muscles. The recommended viewing angle is 15° – 30° [5]. The position of a video display terminal (VDT) relative to eyes can influence visual strain. The two main parameters of VDT position are the viewing distance from the eyes to the screen, and the height of the visual target relative to the eyes [6].

Lighting is an important visual environmental factor for a computer workstation. Salvendy [1] described various types of glare and recommended methods of reducing glare for reflected and direct glare by proper positioning of the screen, using a light-focusing diffuser, adding an antiglare filter, controlling the light source, and a proper adjustment of the screen. Noise can disrupt the ability to concentrate and may produce stress. Salvendy provided solutions to handle noise problems in computer workstations.

Keyboard and mouse are the common interfaces used these days. The optimal posture of the wrist is to keep the wrist straight and free from extension or flexion and ulnar deviation so as to minimize stress [5]. Salvendy [1] made recommendations for an ergonomic and comfortable use of a keyboard and a mouse. They include stability, slope, force, wrist pad, surface, and space for movement.

Different layouts of a VDT workstation were studied. Sotoyama, Jonai, and Saito [7] recommended desk height to be adjustable to the user's height and the monitor to be set closer to the keyboard to provide a smaller ocular surface area. The amount of phobia is smaller in downward than in upward gaze. From a psychological standpoint, dark mergence shifts nearer during downward gaze. This indicated that VDT workers require less visual effort and gain

more visual comfort when gazing downward [7, 8]. Salvendy [1] made several recommendations to improve computer workstation design with regard to work surface and chair.

Work practice is an important issue for computer workstation users. Regardless of how well a workstation is designed, if users have to work in a static posture for a long period, the workstation can contribute to performance, comfort, and health problems. Salvendy [1] recommended computer users to take a minimum 15-min break from working after 2 hrs of continuous computer work. Neuffer, Schulze, and Chen [9] found that at least some improvement in body part discomfort levels could be attributed to mandatory rest breaks.

Occupational illnesses such as back, neck, shoulder, arm, and hand and wrist pain were related to intensive keyboard work, chair and workstation characteristics, increased job demands, poor psychological work environment and being female [10, 11]. Matias, Salvendy, and Kuczek [12] reported that cumulative trauma disorder (CTD) of the hand and wrist was the most common disabling injury experienced by VDT operators.

Ergonomics training programs have shown positive effects in reducing computer workstation symptoms. VDT operators need proper training on how to maintain a correct posture and adjust their workstations [13, 14]. Ivergard [15] provided some ground rules in the design of an education and training program for a computer workstation. The training program was effective in producing positive changes in workstation configuration and posture, and reducing the severity of symptoms. There was also an improvement in productivity [16].

A series of multinational ergonomic intervention studies were conducted to investigate the effects of VDT work on musculoskeletal, visual, ergonomic and psychosocial factors [17]. These studies laid out a basic methodological structure for various ergonomic interventions. The interventions included ergonomic information and training, workstation redesign, and providing new facilities and improved working conditions. A significant reduction in health symptoms,

such as neck and shoulder pain, eye problems, and other ergonomic problems was observed in various groups after the interventions [18, 19, 20, 21].

Although a lot of research has been conducted in this area, it is believed implementation of ergonomics in the office environment is somewhat limited, especially in developing nations. An ergonomic study of a computer workstation in an office environment in the oil industry was of interest. The objective of this research was to study and identify ergonomic deficiencies in computer workstations in typical offices in an oil company and suggest strategies to reduce or eliminate these deficiencies to improve occupational health and safety, and employee performance and satisfaction.

2. METHODOLOGY

The methodology pursued in identifying ergonomic deficiencies in computer workstations involved a physical measurement of the relevant dimensions of workstations, administering

a checklist to collect employee information and a questionnaire on employee perception on various work attributes. The checklist and the questionnaire were constructed by the authors on the basis of the relevant information on computer workstation design in the literature.

A list of the required major dimensions was created from the literature (Figure 1). They included workstation height, chair seat height, seat depth, armrest height, keyboard middle row height, monitor height, horizontal eye-to-monitor distance, eye-to-monitor center distance, shoulder-to-keyboard distance, mouse height, leg minimum height clearance, shoulder-to-mouse distance, angle of knees, angle of elbow, and angle of hips. These measurements were made for each workstation. Besides, noise, light, temperature, and humidity at each workplace were measured.

Noise was measured, in dB(A), at ear height of a sitting employee using a noise level meter; light was measured, in lux, on the employee’s desk using a light meter. A temperature and humidity meter (model TECPEL 322, Taiwan)

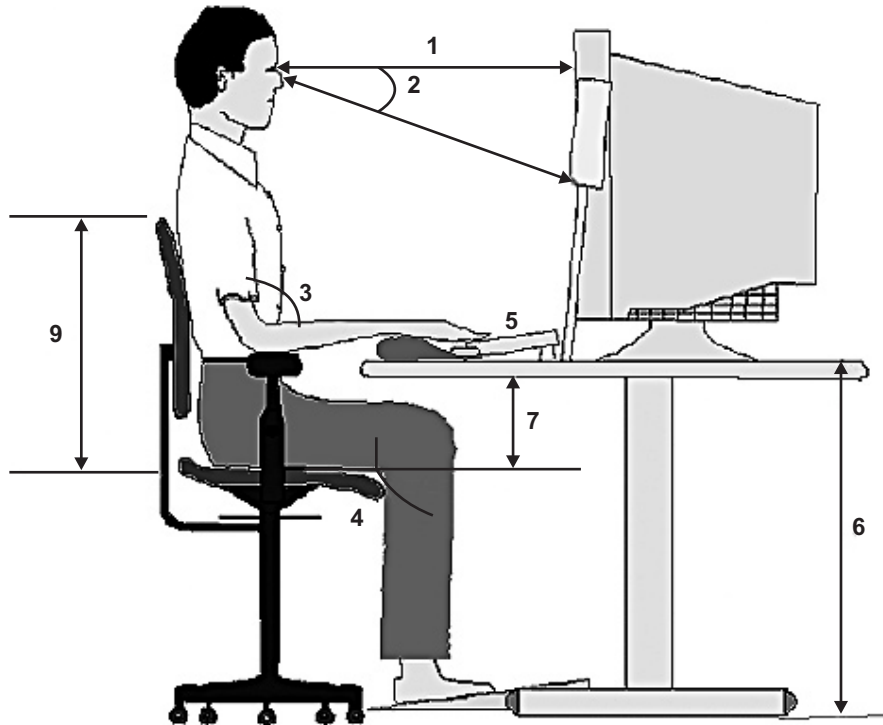


Figure 1. Reference dimensions for the study.

was used to measure temperature and humidity at the workplace. Body posture was assessed through visual inspection. Participants' individual perception on these attributes was assessed through the questionnaire.

The ergonomic evaluation checklist of a computer workstation comprised of four sections: personal information, workstation and work information, medical information, and a satisfaction questionnaire. In all information sections employees were asked to tick Yes or No for each item and in the questions on satisfaction they were required to circle a number from 1 to 5 (*very dissatisfied* to *very satisfied*) that best represented their reaction to a statement. There were 5 personal, 15 facilities-related, 6 posture-related, 12 workstation-related (table, keyboard, monitor, mouse, and chair), 6 screen- and glare-related, 12 health-related, 6 environmental, and 18 satisfaction questions. Five questions on training and 13 questions on dimensions were also included.

Forty computer workstations, each used by one office employee from an oil company were selected for the study. The employees underwent a medical examination before they were employed. Therefore, no medical examination was carried out before the study. The jobs of these employees included computer center support, financial operation services, terminal pipeline operation, and asset management. Therefore, the work regime of the participants could be considered as routine. The offices were fully air-conditioned and between one and five employees occupied each office. All forty employees who participated in the study completed the questionnaire.

3. ANALYSIS OF RESULTS

3.1. Participants' Information

Information on the participants is presented in Table 1. The participants had mean experience of 5 years on such jobs. The group comprised of 80% of men and 20% of women and they were multinationals. Their education ranged from diploma to bachelor degrees. Normal office hours were between 7 a.m. and 4 p.m. with a lunch and two coffee breaks. Their usual computer usage is presented in Table 2.

TABLE 1. Employee Characteristics (n = 40)

Characteristics	M	SD	Min-Max
Age (years)	42	8.29	26-55
Weight (kg)	74	20.69	45-105
Height (mm)	1 680	11.77	1 500-1 850

TABLE 2. Computer Usage Statistics

Duration	Employees at a Computer (%)	
	Per One Sitting	Per Day
1-2 hrs	60.0	0
2-4 hrs	17.5	10
>4 hrs	22.5	90
Total	100.0	100

3.2. Physical Measurements

Recommended standard computer workstation dimensions (min-max) are temperature: 20-27 °C; relative humidity: 50-60%; workstation height: 700-800 mm; chair seat height: 380-520 mm; chair seat depth: 380-430 mm; eye-to-monitor distance: 500-700 mm [1]. Physical measurements of workstations and employee positions were compared with these standard measurements.

TABLE 3. Relative Error (%) Between Measured and Standard Physical Measurements

Parameters	Temperature (°C)	Relative Humidity (%)	Workstation Height (mm)	Chair Seat Height (mm)	Chair Seat Depth (mm)	Eye-to-Monitor Distance (mm)
Min-Max	22.0-27.8	36.80-65.80	660-800	400-520	430-450	370-1110
Maximum relative error	2.9	9.670	0	0	4.65	58.7
Minimum relative error	10.0	2.640	5.71	5.26	13.16	26

Table 3 shows the relative errors calculated using measured and standard dimensions as follows:

$$\text{relative error} = \frac{\text{absolute (measured} \\ - \text{standard)}}{\text{standard}} \times 100\% \quad (1)$$

The highest relative error was for eye-to-monitor distance, while the minimum relative error was for chair and table height. The maximum relative error for eye-to-monitor was 59% and the minimum relative error was 26%, indicating the distance was either much higher or much lower compared to the standard range of 500–700 mm.

3.3. Workstation Components

Eighty percent of the employees used a computer table, while others used a normal office table for the computer. While 55% used a fully adjustable chair (i.e., height, backrest, and arm rest could be adjusted), 45% used a semiadjustable chair (only the height could be adjusted). With a fixed table height (work height) and a semiadjustable chair, workstation adjustment obviously was difficult. Fifty-five percent reported that they maintained a supported and straight back, while 45% reported a bent and unsupported back. This result is consistent with the fact that 45% did not use fully adjustable chairs.

Most employees (98%) had window blinds in their offices. Fifty-three percent used a keyboard wrist pad and 55% used a mouse wrist pad. This indicated that about half of the employees neither used a keyboard nor a mouse wrist pad. This forced hand posture deviation from the natural posture. Only 13% of the employees used a document holder. A document holder can relieve an employee from unnecessary neck movement and poor posture.

The position of the employee with respect to the monitor and the keyboard was aligned in 83% of cases while in others either the keyboard was in front and the monitor on the side or vice versa. This nonalignment indicated repeated turning of head and hence deviation in the neck's natural posture. In 48% of the workstations, the computer screen was facing window, creating a source of glare. This was confirmed when 40% of the employees reported that the window was the

source of glare. Fifteen percent of the employees believed the sources of glare were the windows and overhead lights. Others could not recognize the sources of glare. Twenty-five percent of the monitors were fitted with glare filters.

3.4. Physical Environment

Although the physical environment could be controlled, 25% of the employees reported heat, 23% noise, and 18% light problems in their offices. Measurement of these attributes showed a temperature range of 22–28 °C, noise range of 50–65 dB(A), and light range of 250–600 lux that was close to the recommended lighting levels in offices (relative errors <10%). The variation in temperatures in the offices was due to common office arrangements for some employees and high temperature outside during summer months. Noise could be considered normal. However, telephone noise could be disturbing in common offices and therefore some employees (23%) complained about a noisy environment.

3.5. Health Problems

Health effects or work-related health symptoms were highly significant. A wide variety of health problems was reported: 58% of the employees reported eyestrain, 45% shoulder pain, 43% back pain, 35% arm pain, 30% wrist pain, 30% neck pain, and 23% leg pain. These two dominant problems, eyestrain and musculoskeletal, are indicators of ergonomic deficiencies in office computer workstations.

Eyestrain could be due to computers facing windows producing glare, user-to-monitor distance, long hours of computer use, and inappropriate lighting. Musculoskeletal problems could be due to poor computer facilities, workstation layout, long hours in the same posture, and inadequate rest breaks. Other health issues were also significant.

A correlation analysis was conducted with employee health, work and facilities, and environmental and ergonomic training problems (Table 4). The correlation coefficient of .33 was significant and showed that the employees who did not have ergonomic workstation components

TABLE 4. Correlation Between Ergonomic Problems and Facilities, Environment and Usage

	Employee Health Problems	Work/Facilities Problems	Environmental Problems	Poor Ergonomics Training	All Problems
Employee health problems	—				
Work/facilities problems	.330*	—			
Environmental problems	.254	.037	—		
Poor ergonomics training	.354*	.395*	.445*	—	
All problems	.392*	.764**	.308	.553**	—

Notes. *correlation significant at .05, **correlation significant at .01.

had more health problems than those who did. The positive correlation of .34 between health problems and ergonomic training indicated that those employees who had poor ergonomic training also had more health problems.

No correlation was found between employee health and environmental problems. This was due to a controlled environment that did not have any adverse effect on employees' health. The correlation between health and a combination of all problems was significant. This indicated combined effects of all problems affecting employees' health.

3.6. Employee Satisfaction

An analysis of satisfaction scores showed that a significant number of employees was dissatisfied with various workstation components. Thirty-three percent of employees were dissatisfied with the chair, 20% with the keyboard, and 20% with the number of rest breaks. A correlation analysis showed that employees who had no ergonomically designed components were more dissatisfied than those who did (correlation coefficient .33).

Most employees (82%) had not received any ergonomics training. Among those who had, 54% were dissatisfied with it. No formal or mandatory training program was found in the company except for some booklets and presentations. There was a significant positive correlation between ergonomics training and health problems. Employees with workstation ergonomics training had fewer health problems (correlation coefficient .34) than those who had not had it.

4. DISCUSSION

The study was conducted in a large oil company with 40 office workstations, each occupied by an office employee. Although the sample was small, it represented a typical computer workstation and the results obtained are applicable to office employees using computer workstations.

The study has resulted in a more detailed knowledge on ergonomic deficiencies in office computer workstation and their effects on human health and safety. Physical layout and the dimensions of the workstations indicated a significant deviation from the recommended designs and parameters. It was found that the components of computer workstations did not conform to recommendations. Usual office tables to put computers on, semiadjustable chairs and office chairs, lack of wrist rests, locating computers facing windows, and poorly laid out offices contributed significantly to ergonomic problems.

Reported health symptoms were caused by ergonomic deficiencies in the computer workstation systems. Most participants (58%) complained of eyestrain that could be due to the distance between the user and the monitor, computers facing windows, and spending long hours in front of the computer. Results showed that 55% of employees complained of glare in the workplace that was probably caused by computer screens facing windows. It was found that 48% of employees had their computer screens facing windows. The absolute error of deviation (59%) was maximum for the user-to-monitor dimension. Fifty-eight percent of the computers were facing windows causing glare. These deficiencies

probably contributed to employees' eyestrain problems.

Musculoskeletal problems, such as back, shoulder, and arm pain, were significant indicating effects of ergonomic deficiencies in the workstation system. It was evident from the results that some employees were using office tables for their computers, office chairs, and semiadjustable chairs. Most employees did not have document holders that are important for minimizing back and neck bending, especially for those who spend a lot of time on data entry. There were no wrist rests, either. These conditions, coupled with long hours of computer usage, could cause body discomfort and musculoskeletal problems.

Maintaining a correct posture (upright and natural) at work eliminates unnecessary stress on body parts; hence it reduces musculoskeletal disorders. Forty-five percent of employees were observed bending their backs and not using back rests for supporting their upper limbs. In some cases keyboards were not aligned with monitors and employees twisted their bodies to use the keyboards or look at monitors. Some employees were not using their adjustable armrests. These types of layout could cause discomfort and health complaints.

Although it is recommended that a short break must be taken every 2 hrs of computer use, most employees spent over 4 hrs a day without proper rest breaks. This obviously contributed to health problems as employees continued to be in a fixed posture for prolonged periods.

Employee satisfaction scores indicated that 54% of the employees were not satisfied with the ergonomics training they had received. In fact, training in this respect was only to provide guidance and poster presentations. Systematic training in ergonomics on the layout and usage of computer workstations could have eliminated many of the identified deficiencies. The employees were not satisfied with the types of chairs they were using. Ergonomically designed furniture can reduce postural discomfort and reduce musculoskeletal and postural problems.

Although guidelines and recommendations on computer workstations are available, implemen-

tation of these is lacking, causing serious ergonomic deficiencies in the workplaces.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Based on the results of this study, the following conclusions could be drawn on the ergonomic deficiencies of computer workstation:

- Ergonomic deficiencies were significant in physical design, component layout, employee postures, work practices, and training in office computer workstations.
- There was a positive and significant correlation between worker health symptoms and workstation facilities. Stated otherwise, poor workstation facilities contributed to more health problems.
- Computer workstation facilities and furniture were inadequate, which may have contributed to ergonomic deficiencies in terms of layout and workstation organization.
- Office employees were seldom provided training in proper computer workstation layout and use.
- Absolute error (deviations from recommended standard measurements) was high for viewing distance, which could have contributed to eyestrain.

5.2. Recommendations

The following recommendations were made in order to rectify the ergonomic deficiencies identified for computer workstations in the office environment:

- Computer workstations in offices should be laid out following ergonomics standards, guidelines, and recommendations.
- Employees must adopt a natural posture with back support and follow recommended guidelines in computer workstation usage.
- Ergonomically designed facilities (workstation components) should be provided in order

to better maintain and follow ergonomics standards.

- Employees must be trained in ergonomic layout and organization of their workstations.

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