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Effectiveness of Physical Exercises for VDT Operators

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VDT 작업자를 위한 운동의 효과에 관한 연구

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Abstract

Effectiveness of physical exercise in reducing work-related musculoskeletal stress was investigated. This was compared to the stress alleviation accomplished by using ergonomically designed work station. Tasks chosen for the study were data entry and file maintenance on the video display terminal (VDT). Three different measures, namely root-mean-square (RMS) values of electromyogram (EMG), subjective rating and task performance were used for the evaluation. Electromyograms were recorded from the neck, the left and right trapezius muscles in the shoulder region, and L2/L3 region of the back. Subjects rated discomfort levels for the same parts of their body. Task performance was measured by recording typing speed and errors. Each of the five subjects was tested for two days (8 hours/day) in two different work stations. These were the ergonomically designed adjustable work station and the fixed work station of traditional design with no adjustable features. Assigned physical exercises were performed for four minutes, every two hours during the breaks, by the subjects while working in the fixed work station. It was concluded that the physical exercise could be helpful in reducing musculoskeletal stress as effectively as the ergonomic design of the VDT work station.

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1. Introduction

The science of human engineering serves to make machines work better for people by fitting the task to the man. When this can not be accomplished, the designer is forced to fit the operator to the task. An example of such an adjustment may be the inclusion of rest-breaks in work schedules for an operator to control fatigue and stress.

It is suspected that physical exercise has a potential to reduce work-related musculoskeletal stress. To many people however, physical exercise has been something with which ordinary people had very little to do. The assumption was that only the atheletes performed physical exercise to strengthen their bodies and/or to warm up their muscles before a strenuous exercise. However, this trend has changed since jogging became popular. As people are getting more conscious of their health, they have become more interested in physical exercise or physical fitness activities such as aerobic dancing.

Now the physical exercise has become an important part of the daily life to many of us. Even companies, concerned more about the health of their employees, reward those who take care of their health. Employees also have become more interested in their health for the reward. According to recent time magazine article(Toufexis, et al., 1985), employees at Johnson and Johnson Co. can earn "Life-for-Life dollars" by exercising at least 20 minutes a day and taking other steps to safeguard their health. This article also reported that Fries, the immunologist for the company, has declared "the workplace is the prime location from which to operate the lever of health promotion and disease prevention".

However, people have not taken advantage of or even realized that carefully planned physical exercise can substantially reduce the musculoskeletal stress resulting from certain types of work. Meanwhile, complaints, medical claims and law-suits continue to result because of excessive work related musculoskeletal stress resulting in injuries and illnesses. A lot of employers are trying to improve the situation by designing the work place ergonomically and/or providing technologically advanced equipment or work station. Is this the only feasible solution? Can we take advantage of physical exercise to alleviate the problem?

For a number of years many asian countries including Japan, Korea and China have adopted physical exercise programs in the work place and have successfully reduced the work related musculoskeletal stress. This raises certain questions. Can we implement physical exercise in American or western industry? Is physical exercise really effective in reducing musculoskeletal stress. Is it better than other available method such as ergonomically designed work place or station? Can we simply use physical exercise as an interim solution until management can choose the best method to minimize the musculoskeletal stress at work? These questions are not easy to answer and hardly anyone has systematically studied them. One of the reasons for interest in answering these questions is that the solution has a potential for monetary savings. These savings then, may be spent to improve the work place or to reward the workers or both. This study was conducted as an attempt to seek answers to these questions.

The objective of this research was to study the effectiveness of physical exercise at work in reducing the musculoskeletal stress. The scope of this research was limited to a study of musculoskeletal stress caused by prolonged seating and/or postural limitations. VDT operators were chosen for the study since the large worker population engaged in the VDT work is exposed to the dangerous effects of work related body postures and resulting musculoskeletal stress. The Wall Street journal(September 16, 1985) reported 16.4 million personal computers in use, in the U.S. alone during the year 1984.

It is hypothesized that musculoskeletal stress of the VDT operators can be minimized either by providing sophisticated ergonomic work stations or by implementing carefully designed physical exercise sessions during the work shift. This research is relevant not only to performance and productivity, but also to the comfort of a large segment of the population engaged in VDT use in office or manufacturing.

1-1. Background

There has been a growing concern in the recent years about excessive musculoskeletal stress in workplaces such as VDT and microscope work stations resulting from prolonged seating and other body postures(Grandjean, et al., 1982, Ostberg and Moss, 1984, Kumar and Scaife, 1979, Emanuel and Glonek, 1974). Graham(1986) has warned that excessive sitting on the job may be hazardous to health including a higher risk for colon cancer. He has further stated that exercise causes the body to produce fatty acids that help speed up the waste through the intestines.

Researchers at IBM have stated in their ergonomics handbook(1984) that "holding the same seated position for long periods of time causes fatigue". They suggested implementing body movements in the work routine to reduce the body fatigue. Smith et al.(1981) reported that workers with more flexibility complained less of musculoskeletal and visual stress that workers performing rigid tasks with little control. Troup(1978) suggested incorporating movements in a task to relieve symptoms of postural stress. Ostrom(1981) recommended dynamic sitting of frequent posture change for comfort and promotion of good circulation.

While studing microscope operations at a semiconductor plant in the U.S., Emanuel and Glonek(1974) recommended physical exercise program to reduce work-related musculoskeletal stress. The swedish union report(1983) also suggested intermission gymnastics and relaxation exercises for better health of the worker population. However, none of these studies has shown systematically the effects of physical exercise on musculoskeletal stress. Also, no study has suggested that physical exercise can reduce musculoskeletal stress of the VDT operators.

Most researchers have tried, with partial success, to alleviate this stress by improving the work station design(Grandjean, 1980; Grandjean and Hunting, 1977; Helander, 1981). Some other reseqkarchers have studied the effects of keyboard height on typist performance and preference(Burke, Muto and Gutmann, 1984). National Research Council(1983) stated in its report on VDT titled "Video Displays, Work and Vision" that, of the substantial body of literature on the postural strain associated with VDT work, nearly all is based on subjective reports of muscular discomfort. Therefore, this study employs an objective measure such as the EMG(RMS) values, to measure the levels of muscular discomfort experienced by the VDT operators.

1-2. Rationale

The primary advantages of utilizing exercise to reduce musculoskeletal stress are low cost and ease of implementation. If physic exercise can sufficiently alleviate stress, then it may be substituted for an ergonomically designed work place. Thus, there is a clear need to evaluate the effectiveness of each method in order to optimize the trade off between stress reduction and cost.

However, effectiveness in the reduction of musculoskeletal stress is difficult to be judged in absolute terms unless the reduction is overwhelming. Therefore, the effectiveness of physical exercise should be compared to the effectiveness of a well-proven method for a relative comparision. As was discussed in the background, ergonomically designed work stations have been recommended by many researchers. Thus, the musculoskeletal stress of VDT operators while using the ergonomically designed work station was compared to the musculoskeletal stress of the same operators while using the fixed work station with physical exercise during their rest breaks.

2. Method

The work station design, physical exercise and typing task were the independent variables of interest.

2-1. Work Station Design

Each subject worked in the ergonomically designed work station and in the fixed design(non-ergonomic) work station in a randomly assigned order. In the ergonomic environment the subjects chose the best table and chair adjustments for maximum comfort. In the fixed environment, the subjects worked in the work station with fixed table and chair and performed carefully planned physical exercises. Schematic drawings of the VDT work stations and the equipment used are shown in Fig. 1. The two work station designs are described below.

i) Ergonomic design:
Adjustable CRT screen and keyboard
Adjustable chair and table
Adjustable footrest

ii) Non-ergonomic design:
Fixed CRT screen and keyboard
Fixed table height(72cm)
Fixed straight back chair(43cm high)
No footrest
Physical exercise

The subjects worked for eight hours in each of the work stations. The subjects were required to rest for at least forty-eight hours to eliminate the effects of fatigue from the previous experimental participation. Half an hour was allowed for lunch and fifteen minutes each for the two breaks, during the eight hour period.

2-2. Physical Exercise

In the fixed design work station, subjects

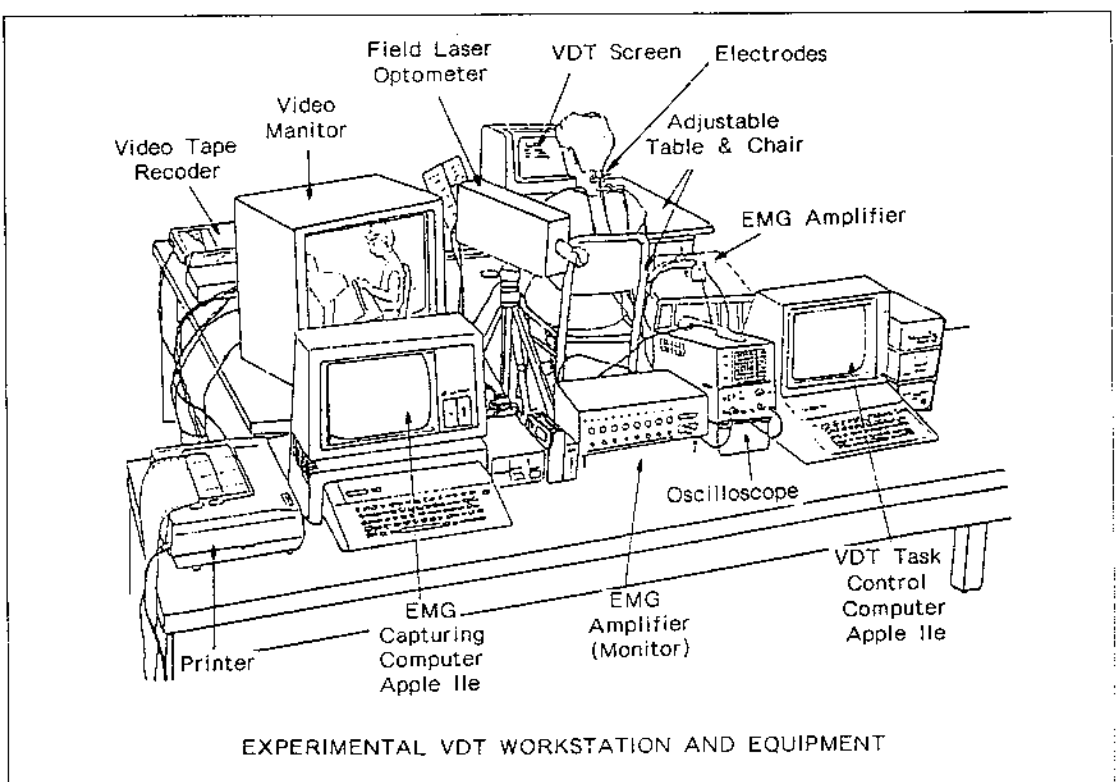

Fig. 1. Experimental Set-up of the VDT Work Station and the Equipment.

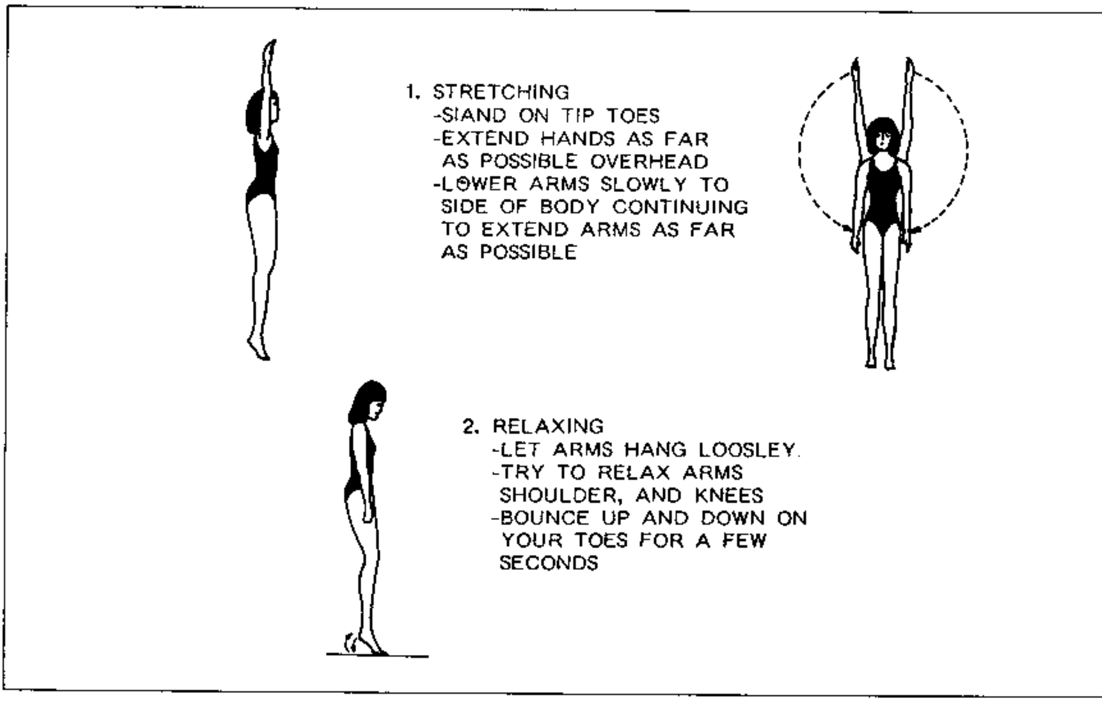

Fig. 2. Illustration of Exercises Used for Streching and Relaxing.

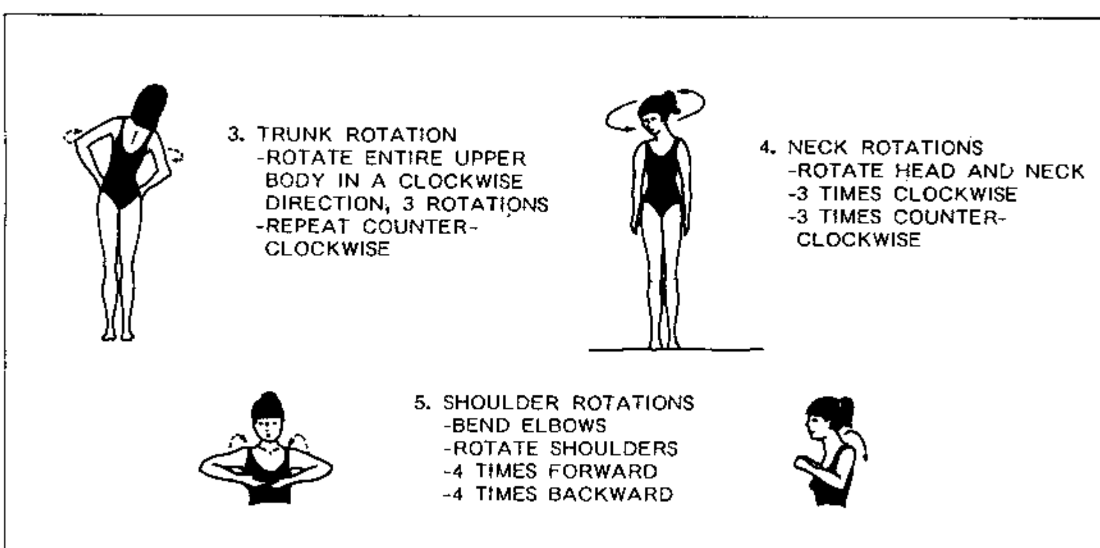

Fig. 3. Illustration of Exercises Used for Trunk, Neck and Shoulder Rotation.

performed 4 minutes of assigned light exercises during each break and lunch time. The exercises were designed from the recommendations of Emanuel and Glonek(1974). The duration of exercises was four minutes. A portion of the exercises consisted of stretching the arm, back, shoulders, neck and legs. There were also neck, shoulder, and back rotations to increase circulation. These physical exercise routines are illustrated in Fig. 2 and 3 with brief instructions for each exercise. Two more routines were also included to give additional back bending and back stretch(Fig. 4).

The other portion of these exercises was designed to relieve eye fatigue by having the subjects focus on different objects at different distances. The effects of this exercise will be reported in other paper(Lee et al., 1986).

2-3. Typing Task

The typing task involved two different sessions; file entry, and file maintenance. During the file entry session, the subjects were asked to type a file carefully, but as fast as possible. During the file maintenance session, the subjects were asked to edit a file containing 40-50% wrong characters as fast as possible. Sessions were switched every 20 files. The typing speed and

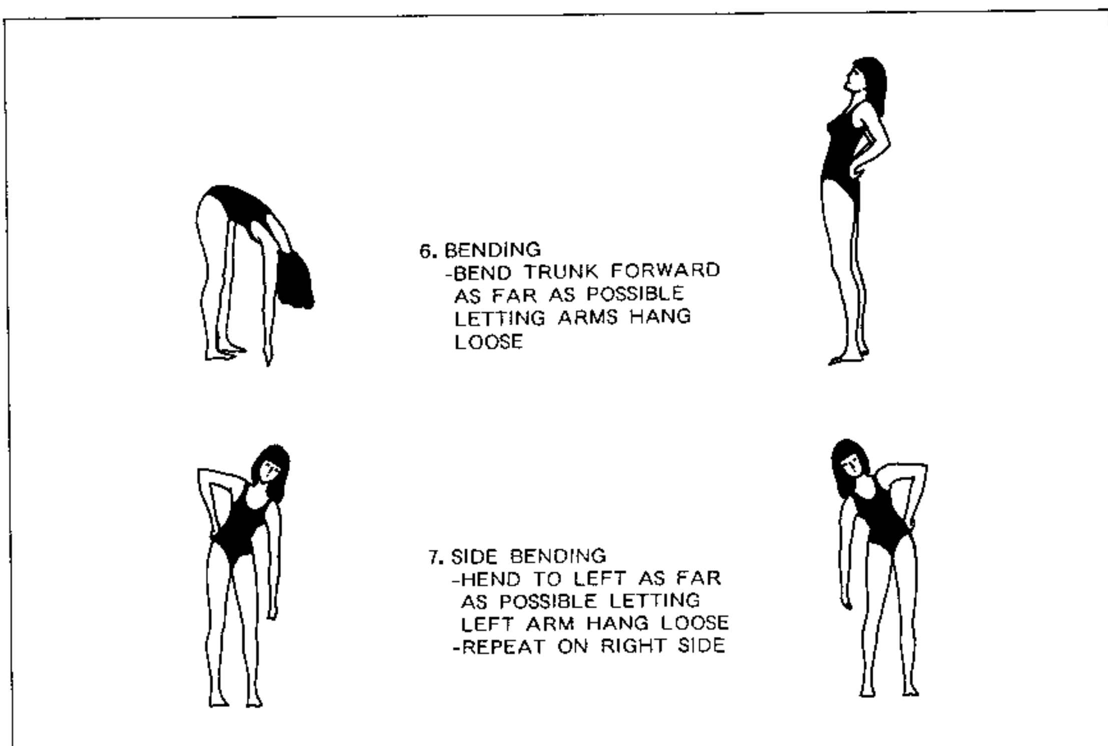

Fig. 4. Illustration of Exercises Used for Trunk and Side Bending.

errors(including extra and omitted characters) were recorded using a computer program developed at NIOSH.

The text provided for typing was developed at NIOSH and averaged 90 characters per file. The characters included alphanumeric symbols, special characters and spaces and corresponded to part name, stock number, manufacturer, street address, city, state, zip code, phone number, bin number, price and location code. The difficulty in reading and typing for different files was approximately equal.

2-4. Subjects

Five subjects, one male and four females, were used in the study. Their ages ranged from 20 to 32 years. All were college students in good health and had no history of musculoskeletal problems. Each had typing proficiency between 60 to 95 keystrokes per minute. They were paid monetary compensation for their participation.

The dependent variables were the musculoskeletal stress, the subjects overall physical discomfort, and the typing performance in a given time period. The musculoskeletal stress was measured by recording the electromyograms from the neck, the left and right trapezius and L2/L3 region of the back. The physical discomfort was measured through subjective questionnaire described later. The typing performance was measured by recording key strokes per minute and number of errors per file.

2-5. Electromyogram Measurement

A good study should be based upon objective measurable data to the fullest extent possible. Responses based upon human judgements, can vary with time and may also be influenced by psychosocial factors. A pilot study performed in the laboratory on musculoskeletal stress experienced by VDT operators, revealed that the application of electromyography may be a feasible method to objectively measure physical stress, without solely relying on subjective human judgements.

The electromyogram(EMG) also provided a quantitative measure of the musculoskeletal stress. This method measures changes in the electrical current in the muscles. Many different measures are used for amplitude and frequency analysis of the electromyograms(Agarwal and Gottlieb, 1983). The peak value, the rectified average value and RMS value of the EMG are generally used when amplitude is of significance. The number of level-crossings(or zero-crossings) per unit time, the number of peaks per unit time and simple band frequency derived from the spectrum analysis are used when frequency is important. Researchers have used other method, however the amplitude and frequency analyses have shown relatively consistent change for fatigued muscle(Basmajian, 1962). For simplicity in computerized data processing, RMS of EMG was used as a criterion measure in this research.

For recording of EMG signals, a pair of silver plated surface electrodes were attached to four body locations. These were the neck, the right and left trapezius muscles of the shoulder region, and L2/L3 region of the back.

A special software program and Apple IIe computer were used to collect the EMG data. The EMG signals were collected at a sampling rate of 500Hz. The data was collected every hour of the subject's working day. The subjects were instructed to stop moving their body and take a standard posture for two seconds for the data collection. This helped minimize the motion artifact effect on the EMG data.

2-6. Subjective Measurement

The subjects were asked to rate their neck, shoulder, back and overall body sensations at the beginning and end of each session. Since the problem areas of the body were identified, it was not necessary to use "Body Part Discomfort Scale" recommended by Corlett and Bishop, (1976). A simplified feeling scale which indicates the degree of pain was used. This was previously developed and used by NIOSH and is shown in Table 1.

2-7. Performance

The VT 100 Terminal, interfaced with an Apple IIe computer was used for the typing task. In order to determine the effect of stress on performance the rate of typing speed(Key strokes per minute) and errors(including extra and omitted characters) were measured for each work station. Typing rates and errors were averaged for each subject and compared for the two work stations.

Table 1. Subjective Feeling Level

Degree of Pain	Feeling
1- 5	Not at all
6-15	Very little
16-24	Somewhat
25-33	Quite a bit
34-50	Very much

Other variables in the picture, suspected not to influence the musculoskeletal stress, were lighting, temperature, noise, and humidity. To minimize the effect of these extraneous variables, their variation was held to a minimum. Blinds on the window were closed, laboratory activity was restricted, and temperature and humidity was recorded in an attempt to monitor the change in environmental factors.

3. Results

Fig. 5 through 8 show the average levels of discomfort and EMG(RMS) values aggregated for all subjects. The discomfort level, averaged over all subjects was observed to be lower immediately following the breaks compared to the levels immediately before the breaks, in both the work stations. Though the subjects were provided rest breaks in both the work stations, they performed physical exercise only in the fixed design work station. This made it difficult to evaluate absolute effect of physical exercise on reducing the musculoskeletal discomfort. However, it is suspected that the subjects working in the fixed design work station environment would have experienced higher levels of discomfort without any physical exercise.

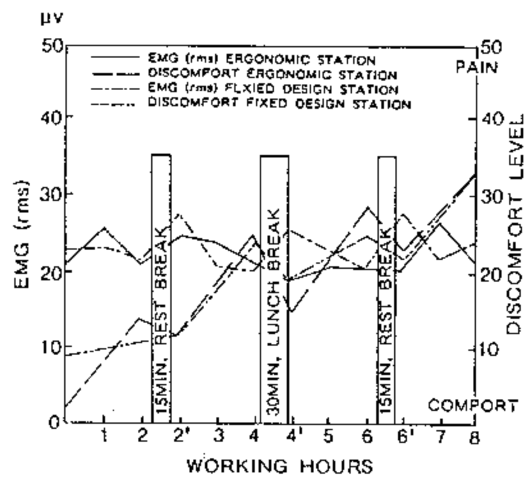

Fig. 5. Average Discomfort and EMG(RMS) of Neck During Working Hours, for Ergonomic and Fixed Design Work Stations.

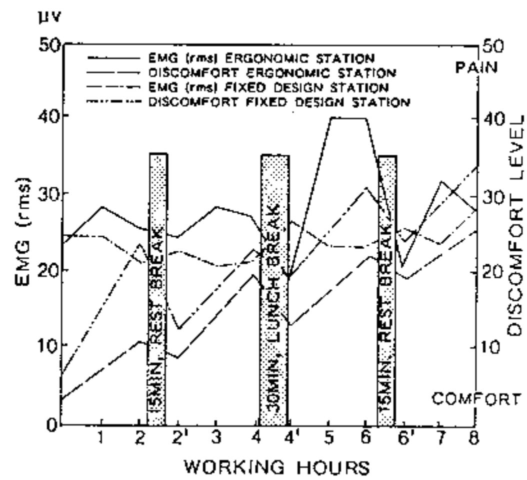

Fig. 7. Average Discomfort and EMG(RMS) of Left Shoulder During Working Hours, for Ergonomic and Fixed Design Work Stations.

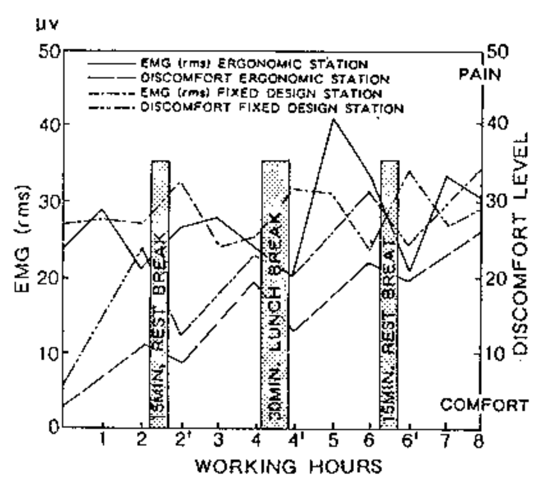

Fig. 6. Average Discomfort and EMG(RMS) of Right Shoulder During Working Hours, for Ergonomic and Fixed Design Work Stations.

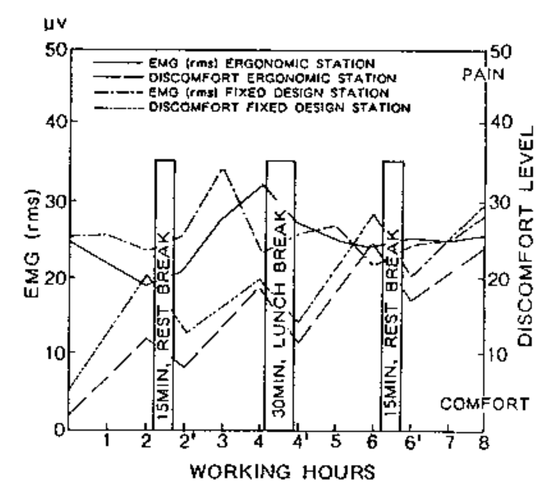

Fig. 8. Average Discomfort and EMG(RMS) fo Back During Working Hours, for Ergonomic and Fixed Design Work Stations.

It can be seen that physical exercise has reduced the level of discomfort in the neck as shown in Fig. 5 and in both the shoulders as shown in Fig. 6 and 7. The statistical analysis indicated that the discomfort levels for both shoulders in the fixed work station environment was significantly lower(alpha = 0.05) than that in the ergonomically designed work station.

Similar saw-tooth pattern of variation in the level of discomfort were observed for the lower back also(Fig. 8). Again, the level of discomfort observed for the fixed design work station was higher than the level observed for ergonomic work station. This may reflect inadequacy of the intensity and/or type of exercise employed for the lower back in the exercise routine assigned. However this difference was not found to be statistically significant(alpha = 0.05). It is suspected that without physical exercise the discomfort levels in the fixed design work station would have been higher.

It may be noted that the overall discomfort levels continued to climb up despite the temporary reductions following the breaks in both the work stations at all body sites where discomfort was evaluated. There were no significant differences in the number and types of complaints of discomfort between the two stations for other body parts. The subjects reported highest level of discomfort for shoulders in the fixed design work station, which may indicate the subjects felt greater stress at this location.

Analysis of EMG(RMS) values showed that the levels of muscle fatigue at all muscle sites studied, were very close in both work stations(paired-t: $t = -5.25 < t(.025, 39)$). It is suspected that without the physical exercise, the muscle fatigue would have been significantly higher in the fixed design work station. Least square regression lines were derived for the EMG amplitude data versus time for each muscle considered, for each work station. To determine equality of the regression lines for the ergonomic station and the fixed design work station, F-test($p < .05$) wa performed for each muscle.

The F-test on the neck ($F = 1.16$) and back ($F = 1.25$) indicated that the two lines were different. But the left shoulder ($F = 3.73$) and the right shoulder ($F = 5.5$) showed little difference in EMG amplitude between the two work stations. This suggests that the subjects experienced less musculoskeletal stress in the right shoulder while working in the fixed design work station with physical exercise. It may be noted that all the subjects were right handed and no bias was introduced due to the differences in the preferred hand.

For none of the muscles, the EMG(RMS) values exhibited the consistently increasing saw tooth pattern that was observed in the subjective measurement of discomfort. However, the regression analysis showed that the EMG(RMS) levels were increasing in general, for both the work stations. This may be seen in figures 5 through 8. Different explanations can be offered for this.

First, no matter how well the experimenter instrcuts or trains the subjects, it is very difficult for the subjects to evaluate their body discomfort well. Secondly, in this study, psychological factors may have affected their evaluation. For example, it appeared that the discomfort was perceived more painful as the boredom increased. Also, it is suspected that the subjects had preconceived idea that their discomfort could only increase as the time progressed and they seemed to remember the previous response recorded one hour earlier. It may be noted that not even a single subject reported lowere discomfort level that one previously reported.

There was no significant difference between the two work stations with respect to average typing performance using rate of typing and number of typing errors per file as criteria(Fig. 9). For the typing entry session, average rate per file was 67 key strokes per minute for ergonomic station versus 65 for the non-ergonomic station. The error rate was 2 errors versus 3 errors per file for the ergonomic and non-ergonomic work stations respectively. For the file maintenance session, the average rate was 48 vs. 47 key strokes per minute respectively, but the subjects made on the average 5 errors in the ergonomic and 4 errors in the fixed design work station.

As seen from Fig. 10, for both the work stations, the typing rate was lower in the second hour of all the two hour sessions. There was no significant difference in the first hour typing rates for the ergonomic and the fixed design work stations. However, a slight increase was observed in the second hour typing rates of the two hour

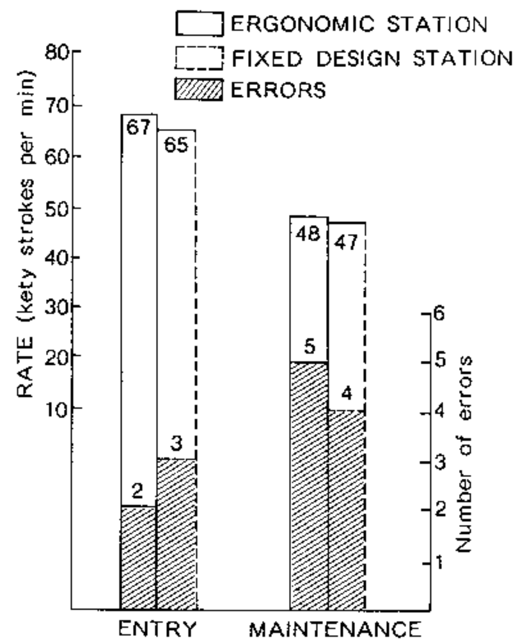

Fig. 9. Average Key Strokes/Minute and Numver of Errors Per File for a Working Day in Ergonomic and Fixed Design Work Station.

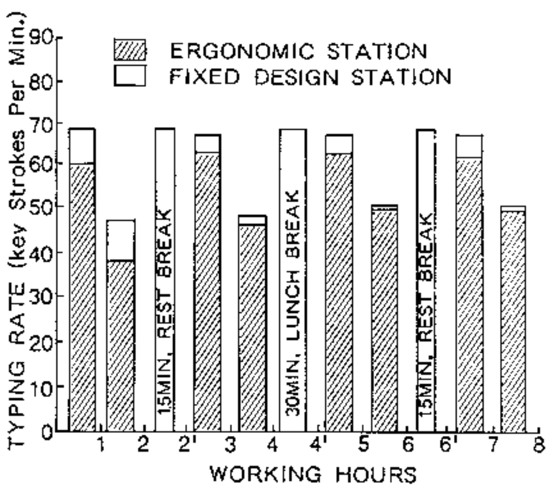

Fig. 10. Average Key Strokes/Minute by Working Hours for Ergonomic and FIXED Design Work Stations.

sessions as the experiment proceeded. For the fixed design work station, this rate increased from 39.5 strokes per minute to 49.5 strokes per minute. The increase was from 46 strokes per minute to 50 strokes per minute for the ergonomic work station as the experiment proceeded. This increase reduced the difference between the overall typing rates in the first and second hours of the experimental sessions.

4. Discussion and Conclusion

Reviewing the results obtained from the electromyographic data for the neck, the left shoulder and the back, no significant difference was found between the ergonomic and the fixed design work stations. Moreover, the EMG trend over time for each body site showed no significant increases in muscle fatigue for the fixed design work station, Especially, the right shoulder showed slightly downward trend for the subjects working in the fixed design work station. Thus, the physical exercise seems to have partially compensated for the deviation from the ergonomic design of the work-station.

The response to the subjective questionnaires for the most part, seem to be similar for both the work stations. However, a slightly higher degree of pain was reported in the fixed design work station: In both the work stations a decrease in the work stations, the ergonomic station was preferred by all of the subjects. However, when the subjects had completed both the experiments, they indicated that the exercises were beneficial while working in the fixed design work station. It was also suggested that the duration of exercises be increased for optimum benefit.

The performance analysis revealed that the subjects performed slightly better in the ergonomic work station. The rate of typing was approximately 3 percent lower in the fixed design work station. However, statistically there were no significant differences with respect to the rate and errors between the two work stations.

Based on the above findings, it may be concluded that physical exercise assigned to the VDT operators working in the fixed design (non-ergonomic) environment can contribute to relaxation of muscles and reduction in muscle fatigue. The contribution may be as much as that offered by the ergonomic features of the ergonomic station. However, all subjects indicated that while they had almost no discomfort at the beginning of the day, they ended up with, very much discomfort at the end of eight hours of work for all muscles studied. This may imply that any one measure might not be enough to substantially reduce the physical stress of VDT operators. Thus, it is recommended that an appropriate combination of ergonomic features and physical exercise be provided for the VDT operators.

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