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INTRODUCTION

This publication is a compendium of NIOSH publications and reports on video display terminals (VDTs). It updates and supersedes the NIOSH document *Publications on Video Display Terminals (Revised)* dated June 1991.

This publication is divided into two Parts:

- Part I consists of full or partial text of selected NIOSH documents on video display terminals. The first document (pages 3-14) provides an overview of the various occupational health issues relating to VDT use. Each of the subsequent documents addresses a specific issue.

- Part II contains a comprehensive bibliography of NIOSH documents on video display terminals. It is divided into two sections: (A) NIOSH-authored documents (which include numbered publications, testimony, journal articles, health hazard evaluations, and miscellaneous reports) and (B) NIOSH-funded documents (which include grant and contract reports). Each document citation includes the title and year of publication and bibliographic or ordering information (see below). Those documents listed in Part II that are reproduced in Part I are noted with the following statement: *(Full [or partial] text included in Part I.)*

All documents listed in Part II may be obtained in one of the following ways:

1. Copies of any document cited with an "NTIS NO" may be ordered from the National Technical Information Service (NTIS) using the order form on page 133. NTIS prices are listed as price codes (e.g., A03). The actual prices corresponding to those codes are shown on the price schedule on page 134. NTIS prices are subject to change without notice.

2. Copies of journal articles, book chapters, and proceedings may be obtained from public or university libraries using the bibliographic information shown in the citation.

Part I

Full or Partial Text of Selected NIOSH References on Video Display Terminals

Environmental and Occupational Medicine, Third Edition, edited by William N. Rom. Published by Lippincott-Raven Publishers, Philadelphia, 1998.

CHAPTER 100

Occupational Health Aspects of Work with Video Display Terminals

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In 1973, Hultgren and Knave first recognized the potential health risks of video display terminal (VDT) use. Since that time, VDTs have become almost ubiquitous in the workplace, and an enormous amount of research has examined their effects on both the design of jobs and the health of workers. The National Institute for Occupational Safety and Health (NIOSH), alone, has conducted several dozen health hazard evaluations and published more than 50 scientific reports on the subject (1). It is not possible to address all of the research findings to date in this chapter; rather, the chapter focuses on key studies to summarize current views on the risks of VDT use. Ergonomic and organizational countermeasures are also discussed. While closure is emerging on some issues (e.g., effects on vision), uncertainty in other areas seems to be increasing. For example, it is becoming increasingly apparent that musculoskeletal disorders among VDT users are not a simple function of biomechanics alone. Data strongly suggest that psychosocial factors play an important etiologic role, although their relative importance and mechanisms of effect are not well understood.

This chapter addresses four health end points: visual system dysfunction, musculoskeletal disorders, stress, and adverse pregnancy outcomes. For each end point we summarize findings on the nature, prevalence, and causes of health or functional disturbances in VDT work; a description of recommendations, as available, for control of these effects is also provided.

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VISUAL SYSTEM DYSFUNCTION

Until recent years, visual system disturbances such as sore, aching, irritated, or tired eyes, and blurred or double vision were at the focus of health concerns in VDT work. Headache is often included in this cluster. Together, these types of disturbances are often referred to loosely as asthenopia, visual fatigue, or simply eyestrain, the expression used in this chapter.

Reviews of field studies of VDT operators suggest that prevalence rates of 50% or more for at least occasional experience of certain eyestrain symptoms are typical (2–4). By far, ocular discomfort symptoms, as opposed to visual imperception, are the most common problems. In one of the first NIOSH studies of VDT users, for example, 75% of VDT users reported occasional aching or burning eyes at work, whereas 39% reported blurred vision (5). (The rates were 27% and 5%, respectively, for frequent or constant problems.) In perhaps the largest epidemiologic study of VDT users ever conducted (over 20,000 Italian workers), burning eyes was the most common symptom (reported by more than 30% of participants). Only half this number reported blurred vision (6).

Eyestrain problems are by no means unique to VDT work. They were described in antiquity (7) and have proliferated in modern times with the increasing near vision job demands associated with the expanding information sector of the economy. Carmichael and Dearborn (8) recognized this growing problem in 1947: "There is probably no single way in which the demands made by modern industrial civilization upon the human organism differ more from those of earlier times than in the requirements made upon the eyes" (p. 1). In this regard, many studies of VDT users have shown that prevalence rates for eyestrain are often comparable to the rates among clerical workers who do not use VDTs (5,9,10).

Health Implications

While eyestrain from VDT use can be a painful and debilitating problem, there is little evidence of pathophysiologic or enduring functional changes in the visual system that can be connected with VDT use. In a comprehensive review of studies seeking objective correlates (e.g., changes in accommodation, vergence, heterophoria, acuity, flicker sensitivity) of reported eyestrain among VDT users, the World Health Organization (WHO) found little consistent evidence of dysfunction (4). In contrast, other studies found shifts in tonic accommodation and vergence following near work and VDT work [see Tyrell and Leibowitz (11) for a review]. Also, the potential for color perception abnormalities following video display viewing is generally acknowledged, but such effects are not known to persist.

With regard to organic disease of the eyes, cataract development in VDT work was once a major concern. This possibility has been discounted, however, by the National Research Council (3), and findings of several subsequent epidemiologic studies have been generally supportive of this position (12–15). In the above-mentioned Italian epidemiologic study of 20,000 VDT users (16), researchers found no connection between the use of video terminals and the early appearance of cataracts, nor with any of nine other pathologic ophthalmic conditions (ocular hypertension, hypertensive retinopathy, etc.). Electromagnetic radiation is the only known VDT-dependent risk factor for cataractogenesis. WHO (4), however, claimed that radiation emissions from VDTs cannot be considered as a credible cause of cataract formation in VDT operators.

In a 1990 reappraisal of risks to the eyes, the WHO concluded, "There is no evidence of damage or permanent impairment to the visual system of persons working with VDTs" (30). This WHO conclusion was based almost entirely on cross-sectional or acute exposure studies. There are, however, some prospective findings that provide supportive evidence. A 2-year study of Dutch telephone operators, for example, showed no deterioration in optometric measures of visual function (17). A more recent, 6-year longitudinal study of visual health comparing VDT users to controls in Australia concluded that there is no convincing evidence to support the hypothesis that VDT use could be harmful to the eyes (18). In comparing year 1 and year 4 data, the study showed no significant differences in the two groups in visual acuity, or in abnormalities of the lens (opacities), cornea, aqueous humor, iris, or pupil. Age, however, seemed to be related to some of the eye abnormalities.

Etiology and Control

As suggested above, eyestrain is a rather imprecise concept. Symptoms are nonspecific and objective signs are lacking. Duke-Elder and Abrams (19) define eyestrain in terms of the symptoms resulting from the "conscious striving" to see. According to this definition, any aspect of the visual environment or of the individual that impairs the legibility or visibility of a visual display is liable to lead to eyestrain.

As summarized below, knowledge exists on ways to maximize the visual quality of displays and on appropriate vision correction to minimize eyestrain among VDT users. Application of this technology alone, however, may be only partially effective in controlling eyestrain from VDT use. The reason is that psychological or motivational factors can intervene to influence the conscious efforts of seeing. This is probably one explanation why eyestrain is unlikely when reading a newspaper or interesting novel, even though the print may be small or of poor quality. In this regard, the very nature of VDT jobs must be considered in assessing potential for eyestrain in VDT work. A recent survey of Swedish public employees found, for example, that eye discomfort among VDT users was related to work organization factors such as lack of work control, high work pace, and time pressure (20).

There are three classes of variables that could influence the legibility and visibility of VDT displays: (1) visual capabilities of VDT users, (2) physical characteristics of the video display, and (3) workplace lighting (which interacts with display characteristics). Only a synopsis of key measures to optimize these variables for VDT work is possible here. Numerous texts provide a more extensive treatment of this subject, as well as quantitative design specifications for high-quality displays (2,21–25).

Vision Correction

Miscorrected or uncorrected problems may be an important cause of eyestrain among VDT users (26–28). Hypermetropes and presbyopes may be at special risk (27,28). In correcting the vision of VDT users it is of primary importance to remember that the viewing distance for VDT images is usually greater, in the neighborhood of 48 to 65 cm (29), than the distance for reading hard copy. This poses a special problem for presbyopes who use reading glasses or bifocals because the video display is usually at an intermediate distance between the far point of near vision and the near point of far vision. Such persons often require special lenses to see clearly without extraordinary effort. Similarly, the customary (lower lens) placement of the near-vision bifocal is often problematic, necessitating an uncomfortable backward tilt and forward flexion of the head for display viewing.

WHO recommends an eye examination for all VDT operators before they begin work, and subsequent examinations beyond age 40 years, especially for persons who report musculoskeletal or eyestrain symptoms (30). WHO recommends that the examiner be trained in visual ergonomics and that examinations include both refraction and visual acuity. WHO cautions against the tinting of eyeglasses for control of glare in the VDT environment. This action could result in unsatisfactory foreground-background contrast on the video display.

DESIGN FEATURES

Video display and workplace design features are believed to influence visibility, legibility, and comfort video display viewing. The American National Standard for Human Factors Engineering of Visual Display Terminal (21) provides perhaps one of the most comprehensive and authoritative guidelines to maximize these parameters. This standard, prepared by the American National Standards Institute (ANSI) and the Human Factors and Ergonomics Society is presently undergoing revision, and an update is anticipated in 1997 or 1998.

Display Characteristics

Character Contrast

A strong character-to-background contrast ratio is one of the most important conditions for comfortable viewing of a video display. In this regard it is critical that screen reflections, both sharp and diffuse, be minimized. The best solution is to reduce excess or stray room lighting (see Workplace Lighting, below); alternatively, filters that can be placed over the display may attenuate reflections. However, these filters (examples include "micromesh" filters, "neutral density" filters, "polarizing" filters) should not be employed without prior testing, since character brightness or sharpness also may be excessively reduced.

Character Sharpness

Character blur can lead to excessive and futile efforts of the eye to bring characters into focus. The culprit may be an aging VDT, a maladjusted focus control, or excessive character brightness (character brightness is often increased intentionally to overcome contrast problems), resulting in radiation of light ("bloom") around the edge of characters, which creates blur.

Character Design

Small or tightly spaced characters and unusual fonts are difficult to discern and create problems in distinguishing among characters, impairing legibility and comfort.

Image Stability

Image instability may result in blur or annoying flicker of the display. VDT images that are created using cathode ray tube technology are inherently unstable, owing to the screen "refresh" process necessary to create the image. However, this type of problem is becoming increasingly rare as VDT technology improves. Excessive character brightness, resulting, possibly, from efforts to improve contrast, increases the ability to detect the instability in video displays.

Color

Characters formed by colors at the ends of the spectrum (blues and reds), are less visible than green, yellow, and white characters. Excessive numbers of colors on the display may also add to confusion, and when the colors are widely separated on the spectrum (e.g., simultaneous use of both reds and blues), some blurring may be perceived.

Image Contrast Polarity

At present, there seems to be little consensus that displays with dark characters on a light background are more or less stressful to the eyes than displays with light characters on a dark background.

Workplace Lighting

The lighting requirements for reading from hardcopy and from video displays are different. Within limits, increases in ambient illumination increase the legibility of paper documents, and in this regard a bright visual environment is desirable in the conventional office setting. A bright office environment, however, creates a risk in VDT work, since it increases the opportunity for screen reflections (diffuse or sharp glare), which are at best annoying and at worst obscure the display. A number of measures, including reorienting VDTs, selective removal of light fixtures, or use of partitions or blinds, may be helpful in controlling room lighting in offices where VDTs are used. The ANSI (21) guidelines suggests the use of a mixture of general and task lighting in the VDT workplace. Task or local lighting can improve the visibility of printed matter, while not impairing the visibility of the video display.

With regard to lighting systems for VDT use, "lensed-indirect up-lighting systems" that distribute the light over a broad area of the ceiling to provide diffuse office lighting was rated more favorably, produced fewer glare problems, and resulted in improved eye comfort in comparison to a parabolic down-lighting system, which uses ceiling recessed fixtures and louvers that direct the light downward (31).

MUSCULOSKELETAL DISORDERS

Musculoskeletal discomfort is as prevalent as, or more prevalent than, eyestrain in VDT work, and has become the primary focus of VDT-related health concerns in recent years. Early NIOSH studies showed a prevalence rate exceeding 75% for the "occasional" experience of back, neck, and shoulder discomfort among VDT users (5,32). In a later NIOSH survey of nearly 1,000 VDT users in two state agencies (33), prevalence rates of 20% to 25% for "almost daily" discomfort in the upper torso were observed. A 1989 NIOSH Health Hazard Evaluation of newspaper employees found that 40% of the 834 participants reported symptoms that met the study case definition for any cumulative trauma disorder during the past year (34). In two more recent NIOSH studies of VDT users, one in the newspaper industry and one in the telecommunications industry, prevalence rates for upper extremity disorders defined by symptoms alone were of a similar magnitude (35,36). (Prevalence rates based on objective signs were reduced to approximately one-half the rates for symptom measures.)

The neck, back, and brachial plexus seem to be a primary site of musculoskeletal discomfort among VDT users. A 1982 Bell System study (10) found neck discomfort to be exceeded only by headache in VDT operators. Neck discomfort was also the only symptom that distinguished VDT operators from controls. Neck pain, followed by shoulder pain, was the most prevalent musculoskeletal symptom in a study of more than 1,500 VDT users in Massachusetts (37). Analyzing VDT users' responses to questionnaires published in a safety and health trade journal, Evans (38) found "painful/stiff neck or shoulders" to be the most common complaint (53% of 4,000 respondents). In the Italian study of more than 20,000 VDT users, back pain and, second, neck pain, were the most prevalent musculoskeletal symptoms (6). Neck-shoulder problems were also most prevalent in studies conducted by Bergquist et al. (39). Recent NIOSH studies indicate, however, that pain at the hand and wrist is also prevalent (36,40). With regard to upper extremity problems in VDT work, much of the current scientific attention seems to focus on carpal tunnel syndrome. Yet NIOSH research suggests that the risk of carpal tunnel syndrome per se in VDT work may be relatively low (35).

As with eyestrain, numerous studies fail to show a significant increase in musculoskeletal symptoms among VDT users in comparison to controls performing related tasks (5,41–43). A recent Scandinavian study found increased risk only for hand and wrist problems (39). (However, most of the studies showed that the prevalence of musculoskeletal discomfort were high in absolute terms for both VDT and non-VDT operators.)

Health Implications

Regarding the long-term health risks associated with musculoskeletal discomfort in VDT use, WHO (4) has concluded that injury from repeated stress to the musculoskeletal system is possible. Dramatizing this possibility, an epidemic of repetition strain injury (RSI) affecting VDT operators swept Australia in the last decade. Five-year prevalence rates approaching 35% were recorded in some Australian organizations (44). Japan experienced a similar phenomenon during the 1970s (45). Some earlier studies suggested that disabling musculoskeletal disorders are becoming a problem among VDT users in the United States (46,47). A recent report by the Office Ergonomic Research Committee (48) indicated that repeated traumas are still growing but their growth rate started to slow down in 1993 and 1994. However, current recording systems make it difficult to determine whether musculoskeletal injuries to VDT users are increasing or decreasing, and the relative contribution of these types of injuries to the rather dramatic increase in cumulative trauma disorders in the United States during the 1980s and 1990s.

Hadler (49) and others (50–54) have argued that musculoskeletal discomfort reported by VDT users represents merely use-associated fatigue or pain, and not underlying pathology. These sources argue that cultural or social conditioning fosters illness beliefs and behaviors among persons who suffer musculoskeletal discomfort (a process referred to as "social iatrogenesis") and that disability then ensues. According to Cleland (52) and The Royal Australian College of Physicians (54), these conditioning forces involve, in part, widely held but false assumptions in the medical and legal community about the seriousness of musculoskeletal discomfort and its relationship to biomechanical demands of VDT work.

Beliefs that musculoskeletal discomfort among VDT users is a benign condition, or that the epidemic spread of disabling musculoskeletal disorders among VDT users is not related to physical job demands, have been challenged by a number of investigators (55–57). Contrary to this viewpoint, several studies have suggested a link between biomechanical stresses and musculoskeletal problems in VDT and keyboard work. Duncan and Ferguson (58) found awkward postures of the upper extremities to be significantly more common among telegraphers with diagnosed myalgia or cramp than among their asymptomatic peers. Hunting and associates (59) reported that deviant postures and lack of arm-hand support were associated with increased discomfort and clinical signs (e.g., pain with palpation and isometric contraction) in both VDT operators and typists. Maeda and colleagues (60) found relatively strong correlations of upper extremity and head tilt angles with arm-hand and shoulder discomfort among accounting machine operators.

Subsequent NIOSH research adds to this evidence. In one study, up to 38% of the variance in musculoskeletal discomfort among VDT data entry operators could be explained by objective measures of posture and workstation ergonomics (33). In a NIOSH study of newspaper employees (34), typing time and speed were significant predictors of upper extremity symptoms. A second NIOSH study among newspaper workers also found a relationship between typing time and hand/wrist disorders (36). Other factors such as static work postures, hand positions, use of lower arm support, repeated work movements, and keyboard or VDT vertical positioning were found to be associated with various upper-body muscular problems (61).

Etiology and Control

Some VDT operators commonly remain seated in fixed, sometimes awkward postures for long periods of time, possibly resulting in increased biomechanical stresses on the back, neck, shoulders, and upper extremities. Additionally, repetition is a concern. Keystroke rates as high as 20,000 per hour are not uncommon for some VDT operators. Some of the biomechanical stresses imposed on VDT operators are subject to control through the careful design and configuration of workstations (chair, table, VDT, etc.). This section begins by discussing measures for reducing biomechanical stresses at the VDT workstation. More detailed, technical specifications are available from several authoritative sources (21,24,62,63). Below is a selective set of chair and workstation characteristics that should be considered in the design of VDT workstations.

Chair Characteristics

Back Rest

A slightly reclining posture is not uncommon for VDT operators and can help to minimize the muscular effort of continuous sitting in an upright posture (64). A slight recline may also reduce lumbar disk forces during sitting (65). To accommodate a reclining posture in VDT work, it is important that the chair have a tall back rest, and that the back rest tilt backward independently of the seat pan. A slightly protruding lumbar support is important in either the upright or reclining seated posture. Vertical adjustability of the back rest will help ensure proper positioning of the lumbar support.

Arm Rests

Adjustable arm rests may help to reduce loads in the back, neck, and shoulders that are created when the arms and hands are suspended over the keyboard (66).

Chair Base

Chairs with five spokes or castors in the base will help to ensure stability.

Seat Pan

Height adjustability of the seat pan will help to achieve a comfortable working level vis-à-vis the keyboard (about elbow level).

Footrest

It is believed that seat pan heights above popliteal height may create uncomfortable thigh pressure or possibly circulatory impairment in the lower extremities. In this regard, many chairs do not adjust low enough for women of small stature, and a footrest may therefore be necessary.

Padding

Padding can be helpful to minimize pressure points at the chair pan, back rest, and arm rests. A rounded ("waterfall") forward edge of the seat pan may also be desirable in this regard.

Workstation Characteristics

Keyboard Height

It is generally believed that loads on the shoulders and elbow flexors can be minimized by positioning the keyboard (home row) at elbow height or perhaps slightly lower (33,67). Some evidence indicates, however, that slight elevation of the table or keyboard may be inconsequential, or even preferred by some workers (68,69).

Knee Envelope

With a thick keyboard or tabletop (e.g., a desk with a pencil drawer), it may be impossible to lower the keyboard to a comfortable height without sacrificing leg room. Restriction of leg and knee room by the table top, table legs, or "modesty panels" beneath the table may lead to highly constrained or awkward working postures. (Constrained postures may also result when the work surface area is too small or designed in such a way as to prevent flexibility in positioning of the keyboard, video display, or other work materials.)

Display Height

Height adjustability of the VDT above the work surface can help minimize biomechanical stresses from awkward head postures in viewing the display. There is general agreement that the primary viewing area of the display should not be positioned above the horizontal line of sight. Views differ on the permissible declination of line of sight; but extreme, downward head tilt should probably be avoided.

Arm/Hand Rests

Cushioned and broad support surfaces (e.g., chair arm rest or wrist rest) for the upper extremities can help to minimize compression or irritation at the wrist, forearm, or elbow.

Adjustability

Implicit in the foregoing discussion is that adjustability of chair and worktable components is important for achieving a comfortable working posture. Not uncommonly, important components of workstations are not adjustable or the mechanisms are difficult to operate. This becomes a special concern when the same furniture is used by several workers. For example, it is unlikely that the workers will bother readjusting the heights of chairs to fit their individual needs unless the chairs have an automatic mechanism that can be operated from the sitting position.

In addition to workstation design, the importance of work organization cannot be overstated as a control measure for biomechanical stresses in VDT work. Work organization (i.e., the way tasks are performed and managed) represents a form of administrative influence over the exposure of VDT operators to biomechanical stressors, including repetition. Examples of promising organizational interventions for VDT jobs include increased rest pauses (70), job rotation, or expansion of jobs to include nonkeyboard work. Work organization is closely intertwined with factors that influence the psychosocial environment and stress at work. Thus, in addition to an influence on exposure to biomechanical stressors, work organization may influence musculoskeletal comfort via other mechanisms.

Work Organization

One of the most significant developments in the study of work-related musculoskeletal disorders has been the implication of psychosocial factors as causal agents. In the most general use of the term, psychosocial factors refer to aspects of the job or individual, or of broader socioeconomic conditions, that result in psychological demands on the individual (and hence can lead to psychological stress). Among the conditions in the workplace that lead to psychological demand and stress are aspects of work organization such as the scheduling of work, aspects of job design (e.g., the complexity of tasks), co-worker and supervisory relationships, management practices, and organization climate/culture. To date, over a dozen major studies have established significant associations between these types of organizational factors and musculoskeletal problems in VDT work (5,36,40,61,71–74). For example, in a NIOSH study of upper-extremity disorders among telephone directory assistance operators, factors such as heavy information processing demands, lack of supervisory support, and time pressure were predictive of objective signs of tendinitis and other neuromuscular and skeletal conditions (35). More recently, Lim (75) found that work pressure and lack of control over work pace were predictive of discomfort, especially in the neck and shoulder regions.

Although extant data strongly suggest an influence of workplace psychosocial stressors on musculoskeletal problems in VDT workers, the mechanisms underlying these effects are still uncertain. In recent years, theoretical frameworks to explain these linkages have been developed by several investigators (75–78). Mechanisms that are common to most of these models are discussed in the following sections. Although knowledge regarding these mechanisms is incomplete, all of these suspected effects stem originally from work organization problems in the VDT workplace.

Physical Mechanisms

As discussed above, it is probable that work organization directly influences biomechanical demands. For example, the complexity of a VDT task is directly related to the degree of repetition in the task (e.g., data entry work is less complex and more repetitive than general secretarial work), thereby influencing biomechanical stresses to the upper extremities. Psychological demand and job stress also vary as a function of task complexity, but their association with biomechanical stress is merely coincidental in this case.

Psychophysiologic Mechanisms

It is well established that VDT or keyboard work can give rise to muscle tension in excess of the demands of keying (79–81). This effect is part of the generalized autonomic adjustment of the body to stress, which also includes increased catecholamine secretion, reduced peripheral circulation, and a variety of other psychophysiologic responses (82). The possible contribution of these effects, especially stress-related muscle tension, to musculoskeletal function and comfort among VDT users is a subject of study by several investigators (81,83,84).

Perceptual and Cognitive Mechanisms

A broad body of research in health psychology suggests that cognitive factors, including psychological stress, are influential in the detection symptoms and in the attribution of symptoms as job-related disease

(85,86). It is plausible that these processes are instrumental in the development of musculoskeletal problems in VDT work; e.g., stress-related arousal may sharpen sensitivity to normally subthreshold musculoskeletal sensations. [Note: This mechanism would incorporate the iatrogenic hypothesis posed by Hadler (49) and others.] However, to date no studies have directly investigated this mechanism in the context of VDT work and health.

JOB STRESS

Until the advent of the industrial revolution, goods were produced by craft workers. Craft workers participate in all aspects of the production process and exercised considerable control over the pace of the job and the way it was performed. With the advent of mass production technology, the organization of work changed dramatically. Mechanization created more standardized, narrow, and repetitive job tasks. Individual control over the work process was replaced by machine pacing and piece work, and workers' identification with the final product was reduced. Occupational stress researchers have come to recognize these conditions as the building blocks for ill health (87).

The nature of office work has been changing in a similar manner. Prior to the advent of the typewriter, office work could still be classified largely as "craft" work. Clerical workers or secretaries were fully and independently responsible for all of the transactions and support functions in the office, the work was varied, and multiple skills were required. Although this form of office work can still be found today, the information age and the mechanization of office work—abetted by the typewriter—resulted in major changes in the nature of office jobs. [See Giuliano (88) for an excellent review of the evolution of office work.] The industrial office functions much like a manufacturing assembly line. Documents are delivered and processed in a serial fashion by successive groups of clerks or information specialists, each performing a very narrow or specialized operation in a standardized fashion. Few workers understand, or could perform, all steps of the job. Piecework, creating heavy workload demand, is common.

Computerization holds the potential for a positive transformation of industrial office work. VDTs make it easier for a single person to create, modify, store, retrieve, deliver, or otherwise process information (i.e., accomplish a skilled and varied task that may otherwise have required numerous separate transactions involving several persons). For example Johansson and Aronsson (89) reported that VDTs enabled agents to obtain a more complete picture of an insurance case and to independently process a claim.

In many cases, however, the introduction of computerization to the office has served only to intensify negative attributes of industrial-age office work. Computerization, for example, has subjected office workers to electronic monitoring of their performance, creating implicit or explicit expectations for heightened productivity and perceptions of increased supervisory control.

Early NIOSH investigations (5,32) were among the first to examine systematically the change in the content and organization of office work associated with the introduction of VDT technology. These studies showed that, in contrast to peers who did not use VDTs, VDT users reported increased work pressure, reduced autonomy, and increased management control over work processes. Furthermore, both studies showed increased disruptions in working relationships between VDT users and their peers and supervisors.

Subsequent studies and reviews of the literature (see refs. 4 and 90 for a comprehensive review) tend to confirm the general pattern of results observed in the earlier NIOSH investigations (although these are effects evident mainly for clerical work). More recent studies highlight additional VDT work-related stress factors, including concerns with computer breakdown and response delays, physical immobility (13), excessive repetition (91), and electronic performance monitoring. For example, electronic performance monitoring of telecommunications workers was associated with increased problems with supervisors and higher levels of reported stress. The combination of electronic performance monitoring was especially problematic when performance standards were enforced, and monitored employees who were barely able to meet the performance standard were the most affected.

Health Effects

There is growing evidence that long-term exposure to the types of unfavorable working conditions that have been observed among some VDT users might have serious health consequences. Accumulating epidemiologic data, for example, suggest that the combination of heavy work-load demands and reduced worker autonomy or control may create a risk for affective disorders and cardiovascular disease.

Although an unusual prevalence of chronic, stress-related psychological or somatic disorders has yet to be documented among VDT users, acute disturbances have been reported in many investigations. A high prevalence of irritability, anxiety, and depressive states among VDT operators was reported in several early studies (32). VDT work is associated with complaints of daily psychological stress. Cardiovascular and neurohormonal responses indicative of increased autonomic arousal have also been reported in persons who perform various types of VDT work. Schleifer and Okogbaa (92) found suppression of sinus arrhythmia and significant elevations in both diastolic and systolic blood pressure when VDT operators worked under incentive pay compensation schedules. Elevations in both blood pressure and catecholamine excretion among VDT operators were reported in relation to faulty computer function (89). Additionally, Tanaka and colleagues (93) reported age-related elevations in catecholamine excretion under conditions of demanding VDT work (e.g., poor display quality).

Recent prospective studies have improved upon the quality of studies of stress and health in VDT work (39,94). In a longitudinal study of office workers, Carayon et al. (94) were able to show that task clarity and ambiguity of job future were associated with worker strain over the 3-year periods. Furthermore, the study also showed that there were different job factors in addition to the above two factors associated with worker strain at each time period (i.e., each year) of the study.

In some sense it may be inappropriate to identify many of these later investigations as studies of VDT work, i.e., implying that the outcomes noted are VDT-related or VDT-specific. Unlike conditions in the 1980s where VDT users worked side by side with office workers who did not use VDTs (thereby enabling studies to reliably attribute outcomes to VDT use), computerization and VDT work is an integral aspect of modern office work and a growing feature of many other jobs. Thus, it is becoming progressively more difficult to disentangle, both methodologically and conceptually, the influence of VDTs from the conditions of modern work.

Controlling Stress in VDT Work

The National Research Council (3) concluded that stress and dissatisfaction in VDT work have resulted from failure to apply to jobs "well-established principles of good design and practice" (p. 2). These principles have been summarized in generic form by NIOSH (97), and described in more specific terms for application in VDT use by Galitz (96), the WHO Regional Office for Europe (90), and Sauter (95).

There is strong convergence among the prescriptions offered by these sources for the design of VDT work. Most sources emphasize, for example, that VDT jobs should be challenging, within the limits of workers' capabilities, and have inherent meaning and value to workers. In this regard, tasks should be sufficiently varied or complex to sustain interest and to utilize acquired skills. Additionally, tasks should have closure, so that each work cycle can be associated with a distinct and meaningful work product. By way of example, most VDT data entry jobs represent the antithesis of most of these conditions.

Most sources emphasize also that the job should provide some opportunities for worker discretion about the way work is organized and performed (e.g., prioritizing, scheduling, and pacing tasks or subtasks). In VDT work it is important that this discretion extend to the physical configuration or design of the workstation.

A third key concern is the social environment at work. VDT jobs and facilities should be designed to enable interpersonal interaction for purposes of both emotional support and concrete assistance in performing tasks. Teamwork or task sharing may help serve this end and help sustain interest in work. Modern offices are often configured in open layouts in which individual office cubicles are created by movable partitions. Depending on the types and positioning of the partitions, this type of open layout can be conducive to workplace interaction. However, this design needs to be balanced against the need for privacy.

Equal in importance to the design of the job is the manner in which VDT technology is introduced to the workplace. Most recommendations emphasize the need for (a) early communications to workers to avoid stressful misunderstandings or uncertainty, (b) early participation of workers to impart a sense of control and to utilize their subject matter expertise, (c) gradual change emphasizing steps with the greatest potential for success and confidence building, (d) training and social or technical support to minimize error and frustration, and (e) avenues of redress to deal with problems while they are still benign (96).

Based on events at the Federal Express Corporation, Westin (98) provides an excellent case example of the design of VDT jobs that conform to these general guidelines. Key to the success of the project was (a) the early formulation of a corporate "people-technology" policy, which espoused, "It is the policy of Federal Express Corporation to systematically incorporate human factors, ergonomics, and job/task design criteria with the development or modification of electronic technology applications"; and (b) development of a standing, labor-management task force to carry out this mandate. Examples of job design specifications under the people-technology policy include teamwork, rotating and combining tasks, and increased deregulation and individual control of work. Importantly, the task force whose responsibility it was to ensure that all design criteria were met was composed of management representatives from all relevant departments (e.g., facilities management, management information systems, safety and health, human resources, risk management), as well as worker participants from the affected production areas.

REPRODUCTIVE EFFECTS

Video display terminals were first associated with adverse reproductive outcomes in 1980, when a cluster of birth defects was observed among women using VDTs at the Toronto Star newspaper (99). The appearance of several clusters led several investigators to conduct epidemiologic studies of the reproductive risk of VDT work (100–115).

Three characteristics of VDT use have been proposed as possible explanations for the observed association between VDT use and adverse pregnancy outcomes:

physical stress, psychological stress, and exposure to electromagnetic fields. Electromagnetic field exposure has been regarded as the most plausible mechanism for possible reproductive effects of VDTs. Two types of electromagnetic fields are produced by the VDT: extremely low frequency (ELF) and very low frequency (VLF) fields. Some review articles offer a detailed review of the literature on VDT use (116) or electromagnetic field exposure (117,118) and reproductive health. This chapter summarizes the VDT literature (100–115). As discussed below, these studies have largely shown no relationship between VDT use and adverse pregnancy outcomes.

Health Effects

Most of the large epidemiologic studies of pregnancy outcomes among office workers have not shown a relationship between VDT use and spontaneous abortion. Of the ten studies of spontaneous abortion, eight have shown no relationship to VDT use (100–107). Most of these studies examined potential risk in relation to weekly hours of VDT use and did not attempt to distinguish between specific risk factors (physical stress, psychological stress, and electromagnetic fields) that might be associated with the VDT. One study that did collect data on job stress and ergonomic work load found that neither factor was correlated significantly with spontaneous abortion (103). A greater risk of spontaneous abortion for women in clerical jobs who reported using a VDT for 20 hours or more during pregnancy was found in one study (108). However, two other studies that examined risk by occupational title did not observe an increased risk for clerical workers (104,106).

Two studies have been conducted that made measurements of electromagnetic fields produced by the VDT (105,109). In one study that measured the electromagnetic fields in the workplace of both VDT users and nonusers, no increased risk of spontaneous abortion was found (105). Measurements of the electromagnetic fields indicated that women seated at VDTs had higher VLF magnetic field exposures than the nonusers or the general population. ELF magnetic field exposures were similar for women seated at VDTs and women who did not use VDTs and also fell within the range of residential exposures. A second study conducted laboratory measurements of electromagnetic fields of the VDTs and found an increased risk of spontaneous abortion among women who used VDT models with ELF magnetic fields measurements over 3 mG at a distance of 50 cm (109). These high emitting VDTs had ELF fields that were about three times higher than the average levels found in other studies in the United States, Canada, Australia, and Sweden (105,116,119,120), suggesting that the exposures VDT operators in this study may not be typical of most VDT users.

Birth defects were also associated with VDT use in some cluster reports, but this association with VDT use was not observed consistently in the five epidemiologic studies that examined birth defects (111). Two studies found no increased risk of major malformations among moderate or heavy VDT users (108,111). A third study found no increased risk for major malformations as a group but found a significantly higher risk for hydrocephalus (110). A fourth study observed an increasing risk of major malformations with increasing weekly hours of VDT use but no greater risk for specific defects (101). A fifth study found an overall excess risk of malformations as well as an increased risk of renal defects (106). Most of these studies had relatively low statistical power to detect increased risks for specific defects, and none measured the electromagnetic fields.

Some investigators have also examined the relationship of VDT use with low birth weight, preterm delivery, or fecundity (15,106,112–115). Most found no increased risk associated with VDT use (106,112–114). One study found a slight, elevation in risk for intrauterine growth retardation in association with more VDT use (104). Another found a slightly increased risk associated with prolonged waiting time to pregnancy among women with greater VDT use (115).

In summary, the weight of the evidence thus far indicates that VDTs in themselves do not increase the risk for adverse pregnancy outcomes. To examine further whether high electromagnetic field exposure constitutes a risk factor for adverse pregnancy outcomes, future studies should focus on populations with higher electromagnetic field exposures than VDT users. In these studies, electromagnetic field exposures should be measured and fully characterized in the workplace to account for all sources of exposure.

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