MICROSCOPE WORK - ERGONOMIC PROBLEMS AND REMEDIES

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ABSTRACT

The widespread use of optical microscopes in industry and medicine has been accompanied by complaints from microscopists about eye fatigue, musculoskeletal strain, stress, and related occupational diseases. This paper reviews literature to be used by NIOSH in disseminating information on ergonomic issues in microscope work.

BACKGROUND

In assessing the potential for health problems in the electronic industry in Asia, Lin (1982) concluded that microscope work was an important occupational health problem. The microscope operators were typically women between 15-25 years of age, and the symptoms of microscope work included headaches, tenosynovitis due to repetitive motions, asthma due to soldering fumes, and possible visual impairment due to prolonged microscope viewing. Simons et al. (1942) reported that sustained voluntary or involuntary contraction of the ocular and/or neck muscles, such as occurs in using microscopes, can give rise to headaches, and pain and stiffness in the neck. In fact, a certain type of musculoskeletal neck pain accompanied by numbness and weakness of an arm, when sitting at a conventional microscope, has been termed "microscopist neuralgia" (Robinowitz et al., 1981). Emanuel and Glonek (1975) found that among microscopists at a major U.S. company, 80% were troubled by headaches or neckaches, 75% by backaches or stiff shoulders, and 75% by eyestrain. A study of hospital's cytology laboratories within the greater Stockholm county revealed that 84% of the microscopists suffered from job related musculoskeletal pain and 82% from eyestrain (Karlqvist and Tapio, 1980).

Dickerson (1976) examined the sources of complaints from a significant number of employees at a worldwide microscope operations company. Management believed that the complaints were closely linked to production problems, and initiated an action plan involving six vision criteria for visual acuity, eye-muscle balance, and depth perception, and eight eye protection codes for working time, microscope maintenance, and eye rest. Using these criteria, Dickerson found that only 73% of the employed microscopists were visually suited for full-time work and another 13% were capable of performing low-power microscope work on a part-time basis. The employment of the remaining 14% had to be terminated based on their inability to meet the minimum visual requirements.

AREAS OF CONCERN

Microscope Myopia

Myopia is a spherical error of refraction. Essentially, it is too much refractive power or, more often, too long an eye for the image of a distant object to be exactly focused on the retina. A temporary, functional or operational myopia can be defined as a situation specific over-accommodation.

One of the first accounts of operational microscope myopia is Druault's (1946) discussion of the visual problems experienced by physicians working at the microscope. He hypothesized that near-sightedness and double vision were the result of undue accommodation and convergence caused by the use of monoucular microscopes. Schober et al. (1970) have shown that operational myopia is indeed more marked with monocular than binocular microscopes. Furthermore, these authors showed that converging ocular tubes gave rise to a substantially higher degree of operational myopia than parallel tubes. According to Baker (1966), inexperienced microscopists have a higher degree of microscope myopia than experienced microscopists.

From a report by Hennessy (1975), it is known that the microscope viewer typically works with an accommodation between 1-3 diopters, which is equivalent to a viewing distance of between 33-100 cm. Furthermore, he showed that the variation in microscope myopia is explained by an individual's involuntary accommodation in darkness or in viewing situations where the eyes are deprived of feedback for depth adjustment: night myopia, instrument myopia, open loop myopia, bright sky myopia, etc. This involuntary response, to become myopic when visual cues are missing, occurs because the eyes adopt an intermediate point of focus. This does not mean, however, that the eyes are at rest when the daytime viewing distance corresponds to the involuntary night/dark focus.

MacLeod and Bannon (1973) suggested that the microscopist should consider the object viewed through the microscope as being very far away in order to avoid viewing with active accommodation. Operators were also recommended to look up from the microscope often to avert a pattern of nearpoint over-focusing. They asserted that the proper use of microscopes should be no more fatiguing than any other normal visual task. However, such a statement is of limited value as "proper use" alludes to the viewing without involuntary accommodation (which is impossible), and as "other normal visual tasks" falsely allude to the microscope task as being a normal visual task. Furthermore, cytodiagnostic microscopy prohibits taking rest breaks by requiring long periods of concentration, which in combination with an anxiety for making detection errors in pathological determinations, sometimes makes the microscope work extremely fatiguing (Johansson, 1981).

It should also be pointed out that many microscopes are designed with converging eyepiece tubes. Whether this is due to optomechanical design solutions or to help the eyes get a fused image of the viewed object, the outcome is that the microscope causes the eyes to converge and accommodate. This is also a factor contributing to microscope myopia.

The Use-Abuse Theory of Visual Impairments

An early article in Illuminating Engineering (1967) gives a colorful description of management's frustration about low productivity due to the microscopists' unwillingness to tolerate such high visual demands and resulting discomfort. Microscopists naturally tend to relate their visual problems to working conditions. Employers, however, typically argue that if the employee meets the visual job criteria, takes good care of the microscope, and follows instruction on how to operate the instrument, then "The only fatigue you should experience is the fatigue felt by everyone at the end of a productive, satisfying day" (Fairchild, 1980). An ophthalmologic research team in Austria found that the accommodation during visually demanding work resulted in a small temporary myopia aftereffect, which could be used as an abuse measure. This led, in turn, to the recommendation that during continuous microscope operations "there shall after each hour's work be at least a one hour switch to a task not involving high visual demands" (Holler et al., 1975).

Similar to Dickerson (1976), Soderberg et al. (1983) were able to define several ophthalmologic factors contributing to microscopists' visual strain at an electronic plant. It was found that 80% of the full-time microscopists experienced various symptoms of visual strain. A statistical relationship was found between these symptoms and uncorrected astigmatism, fusion insufficiency and microscope use time. The authors were convinced that these factors, as well as uncorrected spherical refraction insufficiencies, had a bearing on the development of visual strain, especially in older microscopists.

Zoz et al. (1972) examined 593 microscope workers and found several indicators of marked visual fatigue, particularly among hyperopes and astigmatics. One indicator was that the eye became progressively more myopic during the work day. Visual screening examinations revealed that after six months of microscope work the percentage of persons classified as myopics had increased 37%.

Microscope work seems to be the most demanding work in terms of resultant temporary myopia, but the same consequences can occur for other types of close visual work such as watchmaking, industrial inspection, and cartography (Koitcheva, 1983). Although it is becoming accepted that prolonged work at demanding visual tasks may result in a temporary functional myopia, it is still debated within the ophthalmological community whether this foreshadows a permanent dysfunction (Taylor, 1981). Lanyon and Giddings (1974) and Young (1977) concluded that prolonged exposure to nearpoint viewing was a significant factor in the etiology of myopia. Based on large scale statistical data from the U.S. Public Health Services, Angle and Wissman (1980) convincingly showed that the use-abuse theory <u>is</u> valid, and that visual nearpoint work <u>is</u> a causative factor in the development of myopia. Long-term work at a microscope may thus increase the liklihood that the operator becomes myopic, especially if the microscope work is started at a younger age.

Lighting Aspects

Microscope work often is performed in laboratory-type rooms, with bright and reflecting surfaces, and with a high level of illumination. One method used to solve these lighting problems has been to install tailor-made microscope working cabinets with built-in lighting (Bergkvist et al., 1981; Dickerson, 1980; Illuminating Engineering, 1967). Microscope work also means that the attention is concentrated on a bright field of limited angular extension in an otherwise dark surround, as set by the microscope's built-in field stop and the design of the eyepieces. This means that the eyes are exposed to a field of view with extremely high contrasts between the center and the surround. This contrast may be many hundred times higher than the 3:1 ratio usually recommended for strain free viewing.

Of greater concern, however, is the hazard of having too much light and non-visible optical radiation impinging on the retina. One handbook recommends that older persons "should use the microscope with plenty of light", but later a warning is given that "when a microscope is too bright, a distinct pulling sensation in the front of the eye can be felt" (Burrells, 1977). Another warning comes from a production engineering treatise where it is concluded that microscope operators usually use excessively intense light: "The effects are not noticeable at first, but often prolonged viewing will cause severe eyestrain" (Froot and Dunkel, 1975). A light intensity high enough to cause a "pulling sensation" may also be high enough to cause damage to the retina. A general guideline is that the viewed light is a potential hazard for retinal damage if the luminance exceeds 10,000

cd/m^2. Field measurements indicate that the luminance as seen by microscopists frequently are on the order of 1,000-5,000 cd/m^2 (Bergkvist et al., 1981; Karlqvist and Tapio, 1980; Soderberg, 1978). These luminance levels may still be too high if the optical radiation is rich in short wavelengths (blue light). Fortunately, the predominant wavelengths transmitted through microscopes are in the red or even infrared region and thus have relatively long wavelengths.

The bright but seemingly non-hazardous microscope light could still be of concern because of the fact that microscopy necessitates excessive accommodation. It is not known what a retinal stretch means in terms of altered vulnerability to heat producing light--and accommodation does cause retinal stretch (Enoch, 1975). Secondly, myopia appears to enhance the possibility of retinal detachment (Ogino and Hashimoto, 1978), and light exposure may accelerate the condition of a potential retinal detachment (Lanum, 1978). Taken together, these factors indicate that microscope work could predispose workers for the development of detached retina. This is also the conclusion in a report evaluating a cluster of retinal detachments in workers who welded platinum and gold fine wire under a microscope (NIOSH, 1980).

Posture

Emanuel and Glonek (1975) and Karlqvist and Tapio (1980) found that approximately 80% of full-time microscopists suffered from aches/ pain/stiffness of the neck, back and shoulders. These problems arise because the positioning of the eyes, and hence the posture of the whole body, is closely controlled by the microscope's focal length and the position and inclination of the eyepieces. That these problems can be quite severe is indicated in a report by Kumar and Scaife (1979), who carried out an ergonomic investigation at a plant employing 444 microscope operators. On a typical day, no less than 5% of the workers were found to receive medical attention for work-related musculoskeletal ailments.

Soderberg (1978) studied the postural problems at microscope operations in an electronic plant. She found that 45% of the operators suffered from work-related musculoskeletal ailments, primarily in the neck and shoulder region. The causes of the operator's postural problem was traced to one or more of the following factors (in order of significance): (1) unsuitable location of controls, (2) lack of workable supports for hands and underarms, (3) unsuitable height and angle of eyepiece tubes, (4) a general lack of space and work surfaces, and (5) static posture and/or very small repetitive work movements.

In order to adjust stage position, focus, and light influx, the clinical microscope operators' hands will have to be at the controls more or less continuously. And in industrial operation the hands are likewise involved. Unfortunately, microscope controls are invariably located in positions which force the operator to adopt awkward hand and arm positions, especially if the microscope has been elevated to match the seated operator's eye height.

POSSIBLE ERGONOMIC CONTROL MEASURES

By means of automation, many microscope jobs in industry and health care have already been eliminated; some altogether (blood cell count; micro soldering) and some via the introduction of projection screens (which poses a new set of ergonomic problems). The present review of the problems and remedies of microscope work only looks at the topic from an occupational safety and health perspective.

On Lighting and Microscope Design Recommendations

There is a need for improvements regarding the microscope lighting and the microscope viewing characteristics, but final recommendations cannot be given without further research.

Accommodation is induced by the lack of depth cues, by convergence, and by looking downward. Perhaps microscopists' involuntary accommodation could be diminished by horizontal and parallel eye piece tubes with built-in artificial depth cues. The optics of the microscope could also be designed with the understanding that instrument myopia has to be accepted (Leibowitz and Owens, 1975). Fox and Bahr (1981) suggested that the detail visibility in certain applications could be enhanced merely by using a white stage (increased contrasts). High quality microscope optics may reduce the need for high lighting levels. Microscopes could be equipped with a filter device to cut out the infrared and near-infrared portion of the optical rays exiting the oculars, and a detector device could warn the operator when the visible light is too bright for long term viewing.

On Work Postures Recommendations

Musculoskeletal injuries rank second in the current NIOSH (1983) list of areas for remedial action. From the Swedish 'NIOSH', Soderberg (1978) has suggested that some of the work posture problems in microscopy could be reduced if the ocular tubes would permit a more horizontal line of sight. This idea was adopted by Bergkvist et al. (1981), who created ergonomic accessories for existing microscopes. A favorable report on the benefits of such redesigned microscope workstations has been given by a group of pathologists (Robinowitz et al., 1981). Interestingly enough, another physician suffering severe back/neck/shoulder pain during microscope work has designed a complete "sitting machine" with pushbutton operated adjustments of the table and the chair (see Dickerson, 1980).

Of considerable interest is the recent Swedish Ordinance Concerning Work Postures and Working Movements (1983), which entered into force on January 1, 1984. This ordinance is of interest because of its generic nature (applicable to any type of work) and because its Commentary specifically mentions the need for a good chair for microscope work and also the need for adjustability of the microscope workstation (see Figure 1). The Ordinance spells out compulsory principles for workplace designs, and when these principles, for practical reasons, cannot be met "the person doing the work must be given suitably disposed breaks".

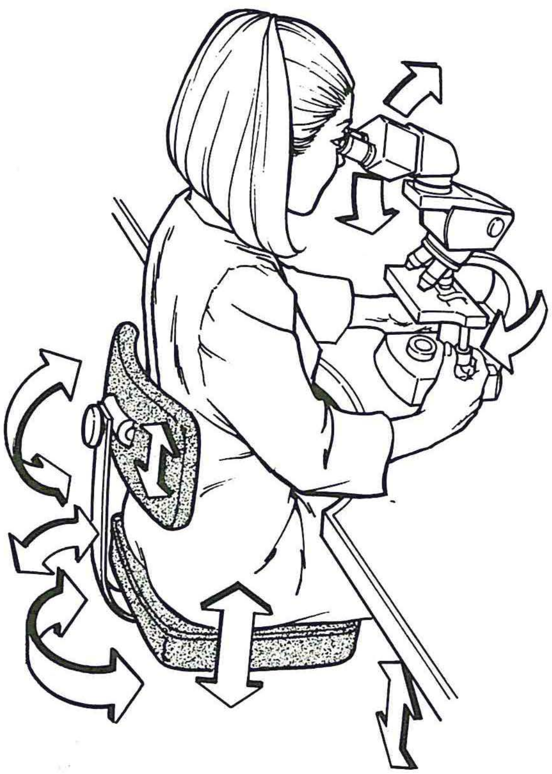

Figure 1. Recommended workstation adjustment possibilities for microscope work. (From the Swedish Ordinance Concerning Work Posture and Working Movements, 1983).

On Work-Rest Break Recommendations

When ergonomic approaches involving redesign of work tasks or equipment are not feasible, then alternatives such as work-rest breaks and shortened working hours must be considered. Ideally, the relief opportunities should be integrated into the work tasks and work procedures, thereby making the work well-balanced (Soderberg, et al., 1983).

A USSR study has classified microscope work in a category requiring reduction in working time (Zoz et al., 1972). Hasselstrom (1976) reported that the USSR limits work time for cytodiagnostic microscopy to 24 hours per week. One of the major Swedish electronics industries recommends that employees carry-out non-microscope work during the last half-hour of a microscope working day, and encourages the use of natural work-rest breaks throughout the day for musculoskeletal relief exercises (Ericsson, 1982). Emanuel and Glonek (1975) recommended the insertion of ten minutes work-rest breaks two hours before and after lunch respectively. During the breaks the employees were advised to spend some time at a relief program consisting of both musculoskeletal and visual/ocular exercises.

Work-rest breaks are equally important where the microscopes have been equipped with projection screens, especially when the operator is required to view the screen for prolonged periods of time. NIOSH (1981) has acknowledged needs for work-rest breaks for operators of visual display terminals (VDTs). These recommendations may be applicable for projection screen microscopes, and could also have a bearing on regular microscope work.

CONCLUDING REMARKS

This review of ergonomic issues in microscope work has taken account of the available research and technical literature dealing with such tasks as well as related visually demanding jobs. Evidence of visual dysfunctions, musculoskeletal strains and general fatigue are significantly recurring themes to dictate concerns and remedial actions. Microscope redesign to offset factors contributing to eyestrain and workstation modifications to ease postural demands are in order. This was also the conclusion of a French workshop on the safety and health aspets of microscope work (ANACT, 1980), the summarizing statement of which was "The operation of binocular instruments is highly fatiguing and merits the highest attention".

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