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DIGITAL EYE STRAIN: SYMPTOMS AND INTERVENTIONS

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ABSTRACT

Extensive daily use of electronic digital for prolonged periods for occupational and recreational purposes can cause an ocular symptom complex (eye-strain, tired eyes, irritation, burning sensations, redness of eyes, dry eyes, blurred and double vision) as well as musculoskeletal problems (neck, shoulder, wrist and back pain). This constellation of symptoms is due to repetitive strain injury (or cumulative trauma injury) and is collectively called "digital eye strain" or "computer vision syndrome". Unsuitable ambient lighting conditions may worsen the ocular symptoms, whereas unnatural posturing while using display devices causes musculoskeletal symptoms. Symptoms are usually transitory, but if frequent and persistent, they can have an adverse economic impact due to increased errors and reduced productivity when professional computer users are affected. Digital eye strain can be subjectively assessed using questionnaires or objectively appraised using several parameters that provide indices of visual fatigue. Customized individual-specific strategies for managing digital eye strain include educating users; modifying ergonomics of the working environment; correcting refractive error and presbyopia; rectifying defective vergence and accommodation; managing dry eye and taking regular breaks while using digital devices. Use of blue light-filtering spectacle lenses have yielded mixed results. Due to the widespread use of digital devices, evidence-based advice and management options ought to be provided.

KEYWORDS: Computer vision syndrome, Digital eye strain, Visual fatigue.

INTRODUCTION

Digital Eye Strain (DES), also known as Visual Fatigue (VF) or Computer Vision Syndrome (CVS),[1] is a complex of eye and vision problems related to the activities which stress the near vision[2] and which are associated with the use of computers (desktop, laptop and tablets) and other electronic display devices (smart phones and electronic reading devices).[3] The terms "digital eye strain" and "visual fatigue" may be more suitable for communication with lay persons, who may not consider devices, such as, tablets and smart phones to be "computers".[3] This repetitive strain injury (also called "cumulative trauma injury") is a consequence of prolonged and uninterrupted focusing of the eyes on electronic digital display devices.[4] Intimate interaction with electronic screens is further enhanced by virtual reality and augmented reality products and by low-cost, smartphone-based gadgets that employ head-mounted displays to create a closed system between the user's eyes. These gadgets also separate the user from the environment by setting the display at much closer ocular proximity than the other electronic display devices.[5]

Interaction with electronic display digital devices or its environment causes visual symptoms,[2] which are usually temporary and disappear at the end of the working day, even though the symptoms may persist in a minority of individuals. In the absence of interventions, these symptoms may get aggravated, requiring frequent breaks and causing increased errors, which may have considerable economic consequences for computer professionals.[6]

Risk factors

The risk factors include prolonged viewing, uncorrected refractive error, use of unsuitable glasses while working on computers and similar electronic display devices, dry eye,[7] glare and reflections from the monitor, strain on the ocular muscles, awkward or unnatural posture while using electronic display devices,[8] non-ergonomic workstation,[9] pre-existing eye disease, female gender,[10] prolonged viewing, absence of screen filter [11] and use of contact lenses.[12] Use of electronic display devices by children should be regulated because they do not report discomfort or other symptoms and they have a propensity for playing video games for prolonged periods with great concentration.[13]

Symptoms

Symptoms include headache, tiredness and burning sensation, excessive lacrimation, red eyes, blurred vision, neck pain, eye strain (or "asthenopia"), double vision, sensitivity to light or glare, changes in colour perception and difficulty refocusing the eyes. These symptoms can be further exacerbated by unsuitable lighting conditions in the immediate surroundings, wrong posture or wrong distance.[14-16] Sheedy et al[17] divided the symptoms into two groups: (a) external symptoms that were associated with dry eye (burning, irritation, lacrimation, dryness) and (b) internal symptoms that were related to accommodative and/or binocular vision stress (strain, ache and headache behind the eyes). Another set of researchers have grouped the symptoms into two categories: (i) accommodation-related symptoms (blurred vision and difficulty refocusing from one distance to another) and (ii) dry eye-related symptoms (irritated/burning eyes, dry eyes, eyestrain, headache, tired eyes, sensitivity to bright lights and eye discomfort).[18] Still others have classified the symptoms into four major groups: (a) asthenopic, (b) ocular surface-related, (c) visual and (d) extra-ocular.[2]

Eye strain (asthenopia): Extended reading, writing, focusing on the screen of an electronic display device, or other intensive "near work" can cause eye strain due to increased exertion of accommodation muscles. During accommodation, the protrusion of the anterior part of lens and change in its diameter from 10 mm to 6 mm pushes the iris forward, which triggers a transient obstacle to trabecular meshwork, resulting in increased intra-ocular pressure. [4] Young computer professionals have been found to have significant increase in intra-ocular pressure in both eyes (with a greater rise in the left eye) after exposure to screens of electronic display digital devices.[7] A female preponderance for asthenopia has been reported.[10]

Dry eye: The human eyes can focus on most printed material, which comprise sharp contrasting images with well-defined edges. The images on screens of electronic display devices are composed of tiny, bright spots (called "pixels") or horizontal lines (called "rasters"). It is difficult for the eyes to maintain focus onto images on the screens of electronic display digital devices (pixels) because they do not have well-defined edges but are brightest at the centre and blur at their edges.[19] Due to the speed at which these images are refreshed or rewritten on the screen by the beam of signals, the blurred image is not seen blurred. The number of pixels or rasters is proportional to the sharpness and clarity of the image.[20] The normal blink rate (20-22 times per minute) is reduced to 4-6 times per minute while using electronic digital display devices, causing evaporative dry eye, which is worsened by air conditioning,[7] direct air currents on the face from ventilation fans, low humidity[2] and general office dust.[20] The users' eyes may hyper-lacrimate in an attempt to restore the chemical balance and re-wet the eye.[2] The prevalence of dry eye increases with age and is higher in women[21] and in contact lens wearers.[22] Dry eyes among females may be associated with higher prevalence of autoimmune conditions[23, 24] and post-menopausal hormone replacement therapy also increases the risk. [25]

Migration of cosmetic preparations onto the surface of the eyes is associated with tear film instability, leading to dry eye.[26] Dry eye has been linked to increased alcohol consumption, certain diseases (Sjorgen's syndrome, rheumatoid arthritis, collagen vascular diseases, thyroid disease, allergy, autoimmune disorders), and use of medications (diuretics, corticosteroids, antihistaminics, antihypertensives antipsychotics, antidepressants).[27]

Musculoskeletal problems

Muscle and joint pain and repetitive stress injuries (also called "cumulative trauma injuries") of the neck,[28] back and shoulder,[8] arm, wrist or hand[29] are caused by awkward or unnatural postures,[8] use of computer mouse and sitting for prolonged periods.[30] Individual factors that determine the occurrence of musculoskeletal disorders include gender, body mass index, physical fitness level, prolonged period of sitting and previous history of illness.[31] Carpal tunnel syndrome is a compression neuropathy of the median nerve as it passes through the carpal tunnel. Several biomechanical factors (forceful exertions, repetitive stress and awkward postures) increase carpal canal pressure with subsequent nerve ischemia.[32-34]

Assessment of digital eye strain

Subjective methods: These include: (a) 10-item questionnaire to evaluate the level of ocular discomfort and facilitate the calculation of a total symptom score,[35] (b) Visual Fatigue Scale (6-item) to study visual fatigue after reading from liquid crystal display (LCD) screens (e-readers, tablets),[36] (c) Computer Vision Syndrome Questionnaire (CVS-Q) for contact lens wearers that facilitates the calculation of a single symptom severity score, called the "CVS score",[12] (d) The first validated questionnaire in English to evaluate DES in the workplace to assess the frequency and intensity of 16 symptoms using a single rating scale (symptom severity).[37] Subjective assessment methods have been employed for further validation of the below-mentioned objective measures of visual fatigue.[38]

Objective methods: (i) ***Critical flicker–fusion frequency (CFF):*** The refresh rate of a monitor refers to the frequency measured in Hertz (Hz) (or times per second), at which the electronic display screen is painted to make an image. "Critical fusion frequency (CFF)" is the refresh rate at which humans can no longer distinguish the pulsating beams of light as separate entities.[39] Prolonged computer use decreases CFF, indicating diminished activity of the retina/optic nerve,[40] which is linked to ocular complaints, such as, pain in or around the eyes, heaviness of eyes and itchy eyes.[20]

At low refresh rates, the characters on the screen may appear to flicker, causing subjective complaints of irritation, fatigue, and headache; whereas at higher refresh rates the image blur is reduced, blink interval is decreased, and reading speed also increases.[41-43] The recommended minimum refresh rate of 75 Hz diminishes flicker at all brightness levels.[44] However, the refresh rates on most high-end electronic display devices range from 125 to 250 Hz.[20]

(ii) ***Blinking characteristics:*** Blinks bring about a cycle of secretion, dispersal, evaporation and drainage of tears,[45] thus facilitating the preservation of a normal ocular surface. Several studies[46-48] have reported that use of electronic display devices reduces blink rate and may be pertinent to development of dry eye symptoms. A reduced blink rate may maintain stability of the tear film if most of the blinks are complete.[49] However, in case of incomplete blinking, the upper eyelid does not cover the entire corneal surface, which can result in increased evaporation and break up of the tear film break up because of reduced thickness of the tear film thickness in the inferior corneal region. Incomplete blinking may lead to exposure keratopathy, lid wiper epitheliopathy, dry eye, refractive surgery, and dry contact lenses.[50]

(iii) ***Accommodation parameters:*** Individuals who are not presbyopes must be able to accommodate quickly to be able to comfortably carry out near tasks.[51] There is delay in accommodation (also called "accommodation lag") when viewing electronic display devices. This lag was found to be higher in 80% of young adult subjects when reading from an electronic display device compared with printed material.[52] Examination of micro-fluctuations that are displayed during accommodative response to a stationary near target may facilitate the understanding of the precision of the negative feedback control system of the accommodative response. [53] Accommodative facility is the ability to rapidly change accommodation response. The eyes frequently fix from the electronic display screen to other material or into the distance.[1]

(iv) ***Pupillary characteristics:*** An increase in pupil diameter during a task adversely affects the depth of focus and indicates visual fatigue.[38] Demanding visual tasks lead to greater increases in pupil diameter.[54] In some individuals, who are involved in intense near work, the pupil may remain fairly constricted with increased amplitude of papillary reflexes, even after the task is completed, which may be ascribed to spasms of the sphincter papillae and ciliary muscle.[55] Post-task pupil recovery can be analyzed by dynamic recording of pupil size and refractive error using an open-view autorefractor.[53]

Interventions

Management of dry eye

Low humidity, ventilation fans, air conditioning and airborne dust/toner particles, which may promote corneal drying.[2] The screens of desktop computer screens and smaller electronic devices (laptop, tablet, e-reader) are often viewed in horizontal gaze and down gaze, respectively. The palpebral aperture is wider during horizontal gaze than in down gaze and therefore, a larger ocular surface area is exposed to the effects of tear film evaporation.[2,3] Use of lubricating eye drops can lead to reduction of symptoms,[56] but not cessation of symptoms.[57] Dietary supplementation with omega-3 fatty acids for 3 months has been shown to render patients symptom-free.[58] Increasing the blink rate through blink training may be helpful.[1] Reduced font size, reduced contrast, increased cognitive demand of task, and spacing between characters and lines tend to decrease blink rates.[43,45] Words with upper case and lower case combinations have better visual tolerance than all upper-case words. Dark characters against a light background display screen are more agreeable.[43]

Correction of refractive Error and Presbyopia

Presbyopic individuals who use ready-made reading glasses (not prescribed by optometrists) and contact lens wearers with under-corrected or uncorrected cylindrical errors are more susceptible to develop symptoms.[1] Use of different digital devices entails a variety of working distances that can be challenging for presbyopic individuals since multiple prescription glasses would be required. Presbyopic persons reportedly prefer using progressive lenses over bifocals while working on a desktop computer since these lenses integrate an area in the top half of the lens for mid-distance viewing of the display screen and a bottom half of the lens for viewing the keyboard.[59] Bilton[60] has suggested the expression "One-Two-Ten" to describe the commonly used distances for currently used electronic devices: (a) mobile phones at a distance of *one foot*; (b) desktops and laptops at *two feet to two and a half feet* and (c) television screens at *10 feet*. Other researchers[61-63] have recommended the "20/20/20" rule – after 20 minutes of using electronic display devices, the user should look at an object about 20 feet away for 20 seconds. Taking intermittent breaks and moving around between computer tasks would prevent eye strain and also reduce the musculoskeletal symptoms.[1]

Management of Accommodation and Vergence anomalies

Frequent short breaks diminish asthenopic symptoms without impairing productivity and can relax accommodative and vergence responses.[64,65] Accommodative anomalies may reduce visual comfort during near-work. Dynamic retinoscopy, wherein the distance-corrected patient focuses on a near target, is used to assess accommodation lag.[66] Vergence dysfunctions (defective binocular vision) include convergence insufficiency, decompensated heterophoria

and poor vergence facility. Individuals with defective binocular vision experience greater visual symptoms with prolonged use of the eyes.[67,68]

Blue light-filtering lenses

Electronic digital devices emit blue light (400–500 nm), which has also been implicated as a cause of DES. Exposure to blue light before bedtime can disrupt sleep patterns.[69,70] Use of blue-light-blocking spectacles in the evening can improve duration and quality of sleep.[71,72] Though there is lack of consensus on the beneficial effects, these lenses have been suggested as a supplementary aid for protecting the eyes against the blue light hazard.[73]

Ergonomics

Recommendations regarding distance of electronic display screen from the user's eyes,[74] the viewing angle[75] and ergonomic design of work stations[9] are more suited for users of stationary desk top computers and cannot be applicable across the board for users of other electronic display devices. While using electronic display devices, the luminance of the room should not exceed three times the mean luminance of the screen.[76]

CONCLUSION

Digital eye strain is a repetitive stress disorder characterized by an ocular symptom complex (eye-strain, tired eyes, irritation, burning sensations, redness of eyes, dry eyes, blurred and double vision) as well as musculoskeletal problems (neck, shoulder, wrist and back pain). Multiple causative factors are linked to occurrence of ocular and musculoskeletal symptoms. Preventive strategies, such as, care of eyes and ocular muscles, modification of the working environment and educational interventions on use of electronic display devices would help prevent morbidity and the resulting loss of productivity. Therapeutic measures ought to be customized for the affected individuals.

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