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Review Article

Computer and visual display terminals (VDT) vision syndrome (CVDTS)

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ABSTRACT

Computer and visual display terminals have become an essential part of modern lifestyle. The use of these devices has made our life simple in household work as well as in offices. However the prolonged use of these devices is not without any complication. Computer and visual display terminals syndrome is a constellation of symptoms ocular as well as extraocular associated with prolonged use of visual display terminals. This syndrome is gaining importance in this modern era because of the widespread use of technologies in day-to-day life. It is associated with asthenopic symptoms, visual blurring, dry eyes, musculoskeletal symptoms such as neck pain, back pain, shoulder pain, carpal tunnel syndrome, psychosocial factors, venous thromboembolism, shoulder tendonitis, and elbow epicondylitis. Proper identification of symptoms and causative factors are necessary for the accurate diagnosis and management. This article focuses on the various aspects of the computer vision display terminals syndrome described in the previous literature. Further research is needed for the better understanding of the complex pathophysiology and management.

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Introduction

With the advent of technological revolution advanced computing cum communication devices have become an integral part of not only professional work but also of leisure activities. In the bargain these computing devices with their visual display terminals (VDT) has now spread their presence from fixed desktop of office space to laptop of a user in bedroom. Moreover adding to its influence extending these VDTs has now slipped into the pockets of billions of mobile users in the form of smart phones. With the unprecedented growth of the users of these handheld devices, it is estimated almost 84% of the world's population will be using these by end of 2018. Paralleling it there has been a steady global increase in the internet usage which is evident from 0.3% penetration in 1993 increasing to 40.4% in 2014. With evidently increased use of computers and its related input devices, a well known clinical entity called ''computer vision syndrome'', gains significant importance. It is an array of clinical symptoms related to prolonged and uninterrupted viewing of VDT (output terminal) or prolonged and repetitive use of its peripherals (input devices). Asthenopia and symptoms related to dry eye disease are the ocular component of the syndrome. In addition to above, it encompasses extra ocular symptoms involving musculoskeletal system, peripheral nervous system and skin. Though VDT use is associated with large number of extraocular symptoms, the eye symptoms are the most frequently encountered complaint among its users.

Using VDTs demands a prolonged near vision task, but the symptoms associated with its use such as blur, dryness and asthenopia are significantly more when compared to similar task without using VDTs.[1] The VDT based activities differ from other near vision tasks by the virtue of complementary influences peculiar to its use. These are device factors, user's personal factors, as well as environmental and ergonomic factors.

Asthenopia and visual disturbances

The prevalence of asthenopia among the VDT users is figured between 55% and 81% in literature.[2] It is related not only to sustained near work but also to a great extent attributed to the use of VDT per se.

Loss of accommodative amplitude and vergence

Qu[3] studied VDT users and compared them with non-VDT users to find that even a short duration of even 1 h working with VDT leads to reduction in amplitude of accommodation, receding of near point of convergence and increase in near lateral exophoria. It is quite evident that computer operation involves prolonged near work. This when studied by Ehrlich[4] it was found that it in turn produces a compulsion for a sustained accommodative effort, which in view of reduced amplitude due to accommodative fatigue demands increased accommodative innervation and onset of subjective visual fatigue. Near triad (accommodation, convergence, and miosis) is almost 1.8 times more in VDT users, when compared to hard copy text jobs. Therefore inaccurate accommodative response (AR), sustained accommodation which is a result of sustained tonic accommodative stimulus presented to the viewer which in turn is due to increased attention span and relatively fixed position of viewer and VDT in an office like environment can be implicated for the above changes. These alterations are temporary changes and have no long-term permanent effect on accommodation and convergence.[5]

Temporarily gadget induced myopia

During a prolonged desk work on a VDT, sustained effort for accommodation is required; due to which an increased demand of accommodative innervations is set in. A small amount of myopic shift has been objectively recorded by various studies on near work induced transient myopia (NITM); among which it varies from 0.12D to 1.3D with mean of 0.4D. Work by Luberto et al.[6] substantiates it association with VDT use to conclude that temporary myopic shift can be a reliable objective assessment tool for VDT related visual fatigue. Though the transient near-work induced myopia is a well known and studied fact in literature but its consequence on permanent myopic shift in adults has been debated. In light of Vasudevan et al.[7] this transiently induced myopia showing additivity of NITM and its delayed decay among early onset myopes may be factors of consideration for contribution in the development of permanent myopic changes among adults and more so in early onset myopes.

Environmental and work factors

Work environment and pattern

The subjective asthenopic symptoms among VDT users have been detected, recognized and accepted as an entity and have been validated by various studies. It is reported more commonly among VDT users by factor of 1.4–1.5 when compared to non-users. Sheedy[8] in his study found that 36.8% of symptoms were as a result of environmental factors lighting, screen resolution and work arrangements.

Surrounding light

The multiple light sources surrounding the workstation have a direct influence on visual symptoms of VDT users. Light from a point or a diffuse source over a VDT reduces the contrast of the text or display on VDT producing annoyance and ocular fatigue. Delivering an insight of the working environmental conditions, Wolska et al.[9] studied luminous flux per unit area of the visual field of operators. Visual fatigue was objectively studied and it found that surrounding illuminance shows bigger changes in visual functions, with no variation between the type of VDT (LCD/TFT). The study showed that luminance of the surrounding visual field influences in the reduction of amplitude of accommodation. Increase in illuminance also has a negative effect on reaction time (RT). Studying color of ambient light, red and green colored lights are found to produce more visual fatigue when compared to white and blue colored lights. The effect of various luminance levels has been

studied by Janosik et al.[10] and it recommended illumination higher than 200 lux at the VDT workstation. Illumination of 300 lux is found most comfortable for entry of figures, whereas 500 lux of luminance is comfortable for edition of text displayed on VDT.[10]

Reflections on screen

Surrounding objects of VDT workstation produce their images on the screen in form of reflections. Reflections generated over the text results in multiple image formation on the screen which starts behaving like a mirror; each such image is varying in depth and focus. It induces confusion with multiple attempts of focus and defocus while reading from VDT. Multiple reflections are produced on the VDT screen, when objectively studied returned with the objective findings of 1.33D of accommodation demand and 2D of accommodation demand for reflections surrounding and reflections on the focal point respectively. These reflections are imaged behind the screen and produce multiple additional conflicting cues demanding an additional accommodation response. The use of antiglare coating as found by Flynn et al.[11] significantly reduces this diffuse light reflecting from the VDT at varying angles thereby reducing diffuse reflection coefficient. In addition it also reduces specular reflection coefficient and glare coefficient to increase the comfort of viewing.

Working hours

The effect of long working hour practices has been found in various studies. Toomingas et al.[12] and Shimai et al.[13] confirmed the fact that long working hours on VDT leads to more visual complaints. Shimai et al.[13] though found that the visual complaints were more with increase of service years and suggested a cumulative effect. Minimum duration (number of hours per day) of VDT use associated with asthenopia has not yet been clearly established. The visual symptom of asthenopia has been found significantly more among VDT workers group who worked more than four hours. On the contrary there are studies which show no significant lowering of asthenopic symptoms among low exposure group with less than four hours of exposure each day. Though, working of more than 8 h per day on a VDT has also been identified as a risk factor for VDT related dry eyes. Less than one hour of single spell of work and work-rest schedule with breaks frequenting at every 15 min followed by microbreaks or at 30 min followed by 5 min breaks has been found to significantly increase work efficiency, reduce eye symptoms and prevent musculoskeletal strain.

Microenvironment

Factors such as low relative humidity (<40%), high temperature and air draft do increase the evaporative disruption of precorneal tear film, producing hyperosmolarity and ocular discomfort. Other factors that may influence or aggravate ocular symptoms in an indoor workplace include dust, pollens, aerosols, combustion products or irritating chemical compounds namely oxidation mixtures formed by interaction between ozone and alkenes at low relative humidity.

Personal factors

Ametropia

Obligation of the accommodative effort among presbyope VDT users increases the stress on already meager accommodative reserve. Presbyopia itself has been identified as a significant factor associated with high incidence of asthenopia. It is also suggested that even small amount of refractory error of equal to or more than 0.5D of myopia, hyperopia or astigmatism increase the subjective discomfort with VDT use. The findings of astigmatic errors of as low as 0.12D increase the eyestrain establishes the fact that even minimal amount of ametropia is a factor, which has a negative impact on visual comfort. Adequately corrected refractive errors and presbyopia when studied objectively, a significant increase in amplitude, velocity and time of accommodation and relaxation was found which possibly explains significant reduction of subjective aesthenopic symptoms with above intervention. A higher satisfaction among users of specially designed VDU work progressive additional presbyopic lenses covering near viewing range from near distances up to 2 m has been found.[14]

Age

With the inception of inducting and recruiting young manpower for handling the desk-jobs involving computer usage, the exposure to the adverse effects of the VDT is now commonly detected among this group. Bhanderi et al.[15] found that early age onset of VDT use is significantly associated with asthenopia. The Osaka study[16] identified age above 30 years as a risk factor for VDT related dry eyes.

Sex

In an epidemiologic health investigative study by Knave et al. evaluated 400 VDT workers and found that Women in general had more symptoms as regards to eye, musculoskeletal and skin disorders which were attributed to prolonged use of VDT. Substantiating above findings a reduced multivariate Hazard ratio model study by Toomingas et al.[12] showed statistically significant association of higher incidence of eye symptoms with female sex. As brought out by Osaka Study[16] VDT associated dry eye disease has also been identified to affect females more than males.

Nicotine use

Nicotine use was studied and its significant association with ocular symptoms was found by Toomingas et al.[12]

Device related factors

Height and angle of VDT

Unfeasibility of modifying height and inclination of VDT has been significantly correlated with subjective visual fatigue and asthenopia. In the present work scenario the ergonomic

attractiveness of LCD TFT monitors has almost replaced CRT VDTs. Studying the effect of different viewing angles of TFT monitor it is found that luminance and contrast are affected with viewing angle. Higher the viewing angle more is the anisotropic effect and lesser performance. They also added that this anisotropic effect is more pronounced in notebook LCD monitors as compared to external LCD or CRT. Studying the effect of viewing distance of VDT Jaschinski et al.[17] found shorter viewing distance and higher monitor positioning increases asthenopia; found preferred placement of monitor between 60 and 100 cm and vertically downward gaze between 0° and −16° by test subjects.

Flicker frequency

Low VDT data refreshing rate below critical fusion frequency (CFF) is perceived as flicker and it contributes to annoyance, headache and visual fatigue. Lower frequency stimulus flicker produces significant accommodation microfluctuation which has an impact on steady state AR, in turn it adversely affects quality (stability and accuracy) of accommodative control but was unaffected for flicker frequency above 40 Hz. Jaschinski et al.[18] investigating effect of temporally modulated light stimulation near CFF and found that at lower refresh rate of 55–90 Hz, mean accommodation in monocular vision was 0.06D lesser, median blink duration was 6% shorter and mean eye blink interval was 15% longer. Minimum refresh rate/frequency of 75 Hz has been recommended by Video Electronic Standards Association (VESA) to reduce perceived flicker irrespective of brightness level of display. The flicker rate is also known to influence the visual space constancy. Lower frequency flickering targets are detected easily during saccadic eye movement when compared to higher frequency flickering target and may distort space perception. Based on his findings, Bridgeman[19] recommended VDT refresh rates more than 120 Hz.

Screen resolution, background and text color

In their experimental study Ziefle[20] found that reading accuracy and speed in significantly more while reading from paper (255 dpi) as compared to lower resolution text of 60 and 120 dpi on VDT (CRT). It also found that reading comfort is dependent on search RT and fixation duration which is lesser in text with higher resolution. It is now an unambiguous finding that higher screen resolution improves perceived image quality and in turn increases the reading comfort and speed simultaneously. Pleasantness and legibility of viewing a text display on laptop LCD monitor is more with dark text-on-light background format. Contrastive color combinations were found most legible and preferred combinations for the LCD monitors.

3D stereoscopic display

To produce a 3D effect on a video display an image disparity is created to fall within the viewers panums fusional area. The images such produced are on a flat surface of the screen which provides a single focal distance, though the disparity of images produces images which appear geometrically in front or behind. This discrepancy between the location of images and their appearance in front or behind leads to convergence-accommodation mismatch and if large it will lead to asthenopia. When compared to the natural stimuli the artificial Stimuli produce diplopic images over the complete display which is well covered within the panums fusional area of a viewer, who perceives sharply focused diplopic images which add to asthenopia. On the contrary such diplopic images occurring naturally are defocused and blurred and are easily neglected. Yum et al.[21] studying influence of 3D display on objective parameters of test subjects found that near point of accommodation (NPA) and near point of convergence (NPC) are significantly altered when compared to 2D display viewing. Further to these earlier findings Yum et al.[21] found that NPC and NPA, both increased more in age group 40–50 years when compared to younger age group of 20–30 years while viewing images with 3D disparity of 3° compared to disparity of 1°. The above parameters were also found to increase more in fast motion in depth 3D display images.

Ocular surface disorder

VDT use has been identified, emerged and implicated as a known influencing factor contributing toward developing dry eye disease (DED) affecting 10–70% of VDT users. An array of ocular complaints such as dry sensation, grittiness, burning, foreign body sensation, increased lacrymation, redness, tiredness, heaviness, and compulsion to blink frequently are reported by professional computer or VDT users.

Spontaneous blink alteration

Blinks are mandatory to maintain the physiologic milieu of the tear on the ocular surface along with its mechanical tear smearing or spreading action. An adequate functioning demands both appropriate frequency and completion of the blinking action. Increase of cognitive demand and attention to a visual task commonly seen with VDT use lead to increased number of partial blinks or blinks in clusters or ''flurries''. Nakamori et al.[22] found that blink rate reduces and maximum blink interval increases during VDT use. Though Chu et al.[23] studying blink rates while reading from a VDT and a hard copy found no significant change in the blink rates between both the methods of presentation but instead there was significant increase of incomplete blinks of 7.02% associated with VDT as compared to 4.33% with hard copy which may be attributed to its drying effect on ocular surface and lid wiper epitheliopathy.

Use of lubricating eye drops is found to regularize inter-blink interval and provides a significant subjective relief in CVS symptoms however has no effect on basal blink rate. Role of omega-3 fatty acid supplementation for 3 months has also been found significant in reducing tear evaporation rate, improving Nelson's grade on conjunctival impression cytology and improving CVS symptoms though no change is seen in tear production. Although the complete effect and role of omega-3 fatty acid are not well understood, it is anti inflammatory effect of its eicosanoid metabolites which is playing a beneficial role. Innovative modalities like moist cool air device reduce tear evaporation rate; antiglare protective

sheet may increase the blink rate; wink glasses improve blink rate, post exposure tear stability and thereby improving ocular surface symptoms.

Meibomian gland dysfunction

Meibomian gland secretions, contributing toward lipid layer of the tear film, are mandatory for deterring evaporative influence on it by ambient air. Wu et al.[24] studying the effect of meibomian gland dysfunction (MGD) on severity of dry eye disorder in VDT users found that lid margin abnormality, meibum expression and meibomian gland dropout (indicators of MGD) were positively correlated with VDT working time of more than 4 h per day. These MGD parameters showed inverse correlation with Tear breakup time (TBUT); positive correlation with fluorescein staining but no correlation was seen with schirmer volumes which can be explained by reflex increase in tear volume produced.

Contact lens wear

The effect of contact lens (CL) wear together with VDT use has been identified to have an additive effect on the development of dry eye condition and ocular symptoms. In their study Tauste et al.[25] reviewed 114 references using scoping review method to find high prevalence of ocular symptoms ranging from 95% to 16.9% among CL users whereas 57.5% to 9.9% among non users. It also found that CL wearers are 4 times more susceptible to develop dry eyes and found silicone hydrogel CL more comfortable. Higher prevalence of dry eyes among CL users has also been substantiated by another study by Tauste et al.[26] Studying the effect of contact lens while working on monitors it is found to have reduced blink amplitude, increased area of tear break-up leading to tear film instability when compared against non-VDT associated task. CLs were also found associated with meibomian gland drop out/meibomian gland atrophy, degraded lipids and lower mole percentage of wax esters in tear films; all of which contributing to the dry eye conditions. Such desiccation of the contact lens surface leads to irregular refraction from the contact lens more so in the hydrogel CLs. These changes reduce best corrected visual acuity particularly more for low contrast text/figures, contributing a visual discomfort factor or even causing asthenopia.

Musculoskeletal symptoms

Musculoskeletal symptoms like neck pain, back pain, and shoulder pain are frequently reported with use of computer. Hales et al. found tendon related disorders (15%) and hand/wrist area (12%) as most common disorder and most common affected area respectively. Nerve entrapment was reported in 4% of subjects.[27] Non-white race, thyroid disease, use of bifocal glasses, and psychosocial variables (like fear of being replaced, work pressure, work-lacking decision-making opportunities) were the other associated factors in upper extremity musculoskeletal disorders among VDT users. Prolonged period of sitting, uncomfortable postures, and mouse use have been linked to musculoskeletal symptoms.

Carpal tunnel syndrome

Carpal tunnel syndrome is a stress related injury caused by compression of median nerve in carpal tunnel due to repetitive movements at the wrist joint. Prolonged mouse use has been recognized as an important risk factor. Adjustable ergonomic keyboards, large forearm support and ergonomic training are effective in preventing and treating of upper extremity musculoskeletal symptoms.

Venous thrombo-embolism

Prolonged seated immobility at workplace has been a risk factor for venous thromboembolism studies.[28] Prolonged computer use is associated with long periods of immobility. The most important factor that plays a significant role in the development of VTE is venous stasis and there is two-third reduction in lower limb blood flow in sitting posture. It has been recommended that workers should get up from their desk or computer every 30 or 60 min to prevent these complications.

Tension neck syndrome

Tension neck syndrome is characterized pain over the neck region and muscle tenderness elicited on palpation and or neck movement. The work related stress over the neck area is influenced by several factors like work station design and individual work technique. The NUDATA (neck and upper extremity disorders among technical assistants) study showed an increased risk of tension neck syndrome with the use of mouse for 15–20 h per week.[29] A similar relation was not found with the use of keyboard. An inner elbow angle $>121^{\circ}$ during keyboard use and armrest is found to have protective effect whereas shoulder flexion $>35^{\circ}$ is a risk factor in the development of tension neck syndrome. An association of tension neck syndrome has been found with limited rest breaks, highly placed keyboards, and use of bifocals.

Shoulder tendonitis, elbow epicondylitis and wrist tendonitis

In a cross-sectional study supraspinous tendonitis and bicipital tendonitis were observed among keyboard users.[30] Similarly, rotator cuff tendonitis was frequently observed in telecommunication workers. Epicondylitis medial or lateral, wrist tendonitis (flexor and or extensor tendonopathy and De Quervain syndrome) may occur with prolonged use of computers. However no association has been found between keyboard/mouse use and epicondylitis in NUDATA study but few cases of epicondylitis have been reported in this study.[31] An increased risk of wrist tendinitis has been associated with the use of wrist support and ulnar deviation of wrist. As repetitive movement and fixed keyboard seems to be risk factors an optimal position of mouse in relaxed, neutral posture of arm combined with the use of arm support are preferred to avoid such problems. The mouse design reducing hand pronation, forearm support with low keyboard and vertical mouse design have been associated with reduced risk of developing wrist tendonitis.

Psychosocial factors influencing musculoskeletal discomfort

According to National Institute of Occupational Safety & Health (NIOSH, 1997) guidelines, there are five workplace psychosocial factors related to musculoskeletal discomfort in computer users: job satisfaction, intensified workload, monotonous work, job control, and social support. Feeling of boredom has been recognized as an important job stressor and related to many health related complaints. Feeling of boredom,[15] high level of perceived work load are factors influencing musculoskeletal discomfort. Computer work under time constraints and lack of support from peer and seniors also contributes to the development of musculoskeletal discomfort. Bhanderi et al.[15] support the association of musculoskeletal discomfort and social support from peer and seniors. As the various psychosocial factors play role in the process of development of several symptoms related to musculoskeletal discomfort among visual display unit users, these also need to be considered before treating patients with computer vision syndrome.

VDT dermatitis

High prevalence of dermatitis such as rosacea, eczema seborrhoeic and erythematitis is seen among VDT users and termed ''screen dermatitis''. Migration of mast cells toward uppermost dermis, its degranulation and release of histamine are found to be responsible for the symptoms of erythema, pain, and edema.[32] Exposure to radiations, electromagnetic field, low humidity are the factors implicated for this 'electrosupersensitivity'/'screen dermatitis'.

Computer use in children

Computer use has been increasing day by day in children both for education and recreation. They may experience the problems similar to adults such as eye discomfort, fatigue, blurring of vision, dry eyes, and eyestrain. Most of the computer stations have been designed for the adult use; therefore, it may not be suitable for the children. They must raise their head in order to view the screen or stand up on their feet. This may further compound the musculoskeletal symptoms such as neck, back and shoulder pain. The most efficient viewing angle which is downward and 15° may not be reached in children which can cause the visual blurring. It is a fact that children are attracted more toward recreational activities viz. playing games which in turn increase cognitive demand reducing the blink rate up to 1/4 to 1/3 of basal rate further compromising the ocular surface.

Points to prevent computer vision syndrome in children

1. Yearly eye examination for early detection of refractive error and or convergence insufficiency and suitable refractive correction and orthoptic exercises if required.
2. Should be allowed a 10-min break after an hour of computer work. Eye irritation due to dry eyes can be treated by putting lubricating eyedrops.
3. The position of computer should be according to the height of child. The computer desk for adult use must be adjustable for the use in children.
4. To check for the lightening condition of room and computer screen to prevent the glare.

Conclusion

Computer vision syndrome is an array of disorders, which encompass ocular, musculoskeletal, dermatological as well as psychological adverse effects among the users of Visual display units in either form. To summarize, appropriate refraction aids, use of higher frequency and higher resolution LED monitors, screen filters, improving the ambient lighting facility, modifying the ergonomic placement of monitors may ameliorate asthenopic component; computer peripheral adjustments like forearm support low keyboard and vertical mouse design may benefit in musculoskeletal recurrent injuries. Use of lubricating eye drops, PUFA supplements and avoidance of CLs and treating any other preexisting ocular surface disorder yield benefit in maintaining healthy ocular surface and preventing related symptoms. The Role of frequent work breaks from the continuous VDT exposure cannot be underrated as it prevents cumulative work induced visual fatigue, ocular surface damage and musculoskeletal injury/strain; all at the same time. Therefore being an outcome of parallel and overlapping multifactorial causes, it mandates multi-faceted critical analysis, tailored intervention for an effective prevention and treatment.

Conflicts of interest

The authors have none to declare.

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