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REVIEW

Spotlight on Digital Eye Strain

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Abstract: Digital Eye Strain (DES) is a clinical syndrome manifested with visual disturbances and/or ophthalmic dysfunction related to the usage of screen-enabled digital equipment. This term is gradually replacing the older term computer vision syndrome (CVS) that focused on the same symptoms found on personal computer users. DES is encountered more frequently during the past years due to the explosive increase in the usage of digital devices and subsequent increase in time in front of any screens. It presents with a series of atypical symptoms and signs stemming from asthenopia, dry eye syndrome, preexisting untreated vision issues and poor screen ergonomics. This review summarizes research data to date to determine whether the concept of DES has been conclusively defined and demarcated as a separate entity and if sufficient guidance is offered on professionals and the lay public. The maturity of the field, grouping of symptoms, examination techniques, treatment and prevention modalities are summarily presented.

Keywords: digital eye strain, computer vision syndrome, classification, management

Introduction

Vision problems attributable to prolonged viewing of screen-enabled digital devices have been reported since 1987[1] with an article detailing both ocular and orthopedic issues that were related to spending long hours in front of a computer terminal. Initially, the focus of research was the workplace, since screen-enabled devices were predominantly used for professional purposes due to their cost and size. However, the focus was expanded outside the workplace with the advent of home computing and the gradual reduction in size of screens with the shift from cathodic ray tubes to liquid crystal displays (LCDs) and light emitting displays (LEDs).[2] "Terminology has changed as well, with the initial terms, which were limited to computer use" (computer vision syndrome – CVS) gradually expanding to "Digital eye strain – DES",[3] a term coined to include any type of digital screen. In either case, both terms, CVS and DES, have come to signify a clinical syndrome, which includes numerous eyesight symptoms related to lengthy engagement in front of a screen-enabled digital device.

DES symptoms are perceived as various degrees of irritation, which interferes with further screen viewing. Symptoms generally recede after some time away from the screen and receiving symptomatic treatment, while they may be prevented by correcting pre-existing errors in refraction or viewing habits. Although this syndrome has been widely reported and its existence even acknowledged by a number of professional bodies,[4–7] its transient nature and wide variance of symptoms leads to challenges with classification of cases, assessing its prevalence and stipulating recommendations for both the professional and the lay public. Estimates of prevalence range from 33% of the general public, up to 50% for groups that are using digital screens for an extended period of time, as for example were children and college students following classes online due to restrictions imposed during the COVID-19 pandemic.[8,9] These studies also demonstrate a clear increase of symptoms, which was proportional to the increase on time spent online. Symptoms overlap with, or are dependent on the existence of other nosological entities, such as dry eye disease or various causes of uncorrected refraction. The syndrome also includes symptoms of extraocular origin that are attributed to poor ergonomics of the environment where screen viewing takes place and are thus outside the immediate attention of the optometrist or ophthalmologist who would evaluate the patient. Despite these objective hurdles in assessment, a recent anonymous

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survey of 406 optometrists in the UK and Ireland[10] found that the vast majority of respondents were in agreement that DES is an important concern for the profession (88.9%) with 91.4% responding that they felt confident in discussing symptoms and management options. It thus appears that adoption of DES is driven by necessity, despite those difficulties in its exact definition and classification. The purpose of this narrative review is to evaluate the significant body of research evidence that has accumulated over the years and determine whether the concept of DES has been conclusively defined and demarcated as a separate entity, and if sufficient guidance is offered on professionals and the lay public. We have opted for a narrative review, which focuses on recent developments, since the subject has been studied extensively for considerable time.

Materials and Methods

A search on PubMed with the most frequently employed terms ("digital eye strain", "computer vision syndrome" and "video game vision") returned more than 500 results. Interest has grown exponentially ever since the first related publication on 1987,[1] with nearly 400 articles published during the past ten years and 280 within the past five. Thirty-five articles since 2002 have been reviews of previously published material[11–43] and this article will present a synthesis of their findings and recommendations along with a limited number of guidelines and recommendations for the public from professional bodies. The latter include those of the American Optometric Association (AOA),[5] American Academy of Ophthalmology,[4] UK College of Optometrists[7] and Canadian Association of Optometrists.[6]

Review

Maturity of the Field

Among this large number of reviews, the field appears to have matured enough to include suggestions for some very specific instances and special populations, such as children and adolescents.[11,17,29,42] Video gamers,[32,36] contact lens wearers,[18] specific occupations and work environments.[18,34,41] The conclusion is that there is sufficient body of evidence to draw conclusions regarding DES, provided there are no major changes in the way that screen-enabled devices are used in the near-future. This may change with future technological advances that will permit a near-field experience of digital visual content. The publication of the four sets of official guidelines and recommendations for the public[4–7] appears timely.

Recommendations from Professional Bodies

Three professional associations have offered guidance for symptoms of DES to either the public or to professionals. The American Optometric Association has an online presentation of DES with useful information for professionals and patients alike, including tips on office ergonomics and suggestions for patients in order to alleviate the symptoms.[5] Although the content is useful, the mixed nature of the presentation, which switches from a more professional note to suggestions for patients, is somewhat confusing.

The American Academy of Ophthalmology has an extensive online presentation, which includes information for the professional and the lay public.[4] Although some effort was made to catalog this information in a logical manner, there are interspersed sections that include a list of potential issues with video display terminals outside the scope of DES (radiation, link to cataract formation, usage during pregnancy, sleep and neuro-psychiatric issues) and recommendations for children's activity levels. Recommendations for management also venture outside the scope of DES. Overall, there is useful information available but in need of a reflow to separate sections.

The Canadian Association for Optometrists is addressing the lay public with a simple online presentation of possible symptoms and practical advice for self-help and prevention.[6] There is a set of simple questions regarding the usage of screens for the patient when visiting a professional which should ideally be read beforehand; these include duration of use, distance to the screen, workstation setup and lighting. Tips on ergonomics and rest time between screen sessions are offered along with the possibility of using artificial tears for dry eye symptoms and appropriate lenses for refraction issues.

The UK's Royal College of Optometrists does not formally employ the term DES on its website. However, it does offer guidance for professional practice when examining patients who work with display screen equipment or

computers.[7] There is no suggestion that patients may be affected by other types of screentime however and the overall focus is on symptoms of DES from the viewpoint of a professional hazard.

Despite the existence of those recommendations from official professional bodies, there is little in the way of commonly accepted attributes for DES. This is apparent in the employed terms, the clinical symptoms and signs, the diagnostic procedures and the suggestions regarding prevention and treatment.

Terminology of Choice

Along with DES, the term "CVS" still persists in the relevant literature up to 2022.[2,5,16,20–24,28,37,44] There is no clear rationale for choosing one term over the other on offer in any publication or official set of recommendations, while some authors include both terms.[4,6] The term "CVS" appears more in line with accepted medical terminology since it implies the existence of a specific syndrome in the domain of vision. However, the keyword "computer" is very limiting in the day and age where computational powers are embedded in a wide variety of handheld and household appliances whose principal use is other (eg, smartphones, TVs, etc.). DES as a term, on the one hand, is more suitable to the source of the problem (all things digital) and appears more friendly to the lay public, yet limits the description to the sense of eye strain. Clearly both terms are not sufficient to describe the clinical syndrome and its causes. However, establishing yet another term would be counter-productive. Hence, our suggestion would be to prefer the employment of the term DES since it will be more easily conveyed in a public initiative to attract attention to the issue, an important consideration since the syndrome is affecting children and adolescents to an alarming extent.

Attributes of DES as a Clinical Syndrome

A large number of symptoms and signs have been associated with DES and these overlap in nearly all publications. They can be divided into four major categories (Table 1).

Table 1 DES Symptom Categories and Diagnostic Procedures

Symptom Categories	Symptoms	Underlying Causes	Suggested Diagnostic Procedures
Asthenopia symptoms	Eye strain, pain, diplopia, blurriness, halo	Prolonged fixation to near-field viewing leading to exophoria, convergence insufficiency, low fusional convergence, decrease of accommodative amplitude and temporary myopic shift	Horizontal heterophoria assessment with Howell's near and far test, vertical with Thorington's test, assessment of near point of convergence, accommodative convergence/ accommodation ratio with a +1.00D flipper lens, stereopsis with Titmus test
Dry eye symptoms	Irritation or burning sensation, feeling of foreign body, watery eyes, red eyes, photophobia	Reduced blink rate when fixing gaze to screen and increased exposure of the eye due to horizontal gaze. Also, possible role for pollutants of air on workplace	Traditional: Tear film break-up time test, Schirmer test. Novel: non-invasive tear breakup time, thermography, anterior segment optical coherence tomography, meibography, interferometry, in vivo confocal microscopy, and optical quality assessment
Symptoms of other eye conditions	Symptoms similar to asthenopia, headache, difficulty to focus on fine print and need for more ambient light	Uncorrected astigmatism or/and presbyopia, any clinical cause of abnormal binocular interaction including strabismus, anisometropia, unilateral cataracts, corneal opacities.	Appropriate procedures for examining refraction and visual acuity, Hirschberg corneal reflex test, assessment of stereopsis, binocular single vision assessment, color vision test, optical field assessment
Poor ergonomics	Muscle pain and stiffness, tension headache	Suboptimum relative viewing position to screen in a work setup, holding unnatural posture when handling handheld devices, prolonged viewing time in general without breaks	On-site assessment of ergonomics at work, patient description of ergonomics at home or work and description of usage patterns for handhelds

(a) Symptoms and signs of asthenopia.

Asthenopia, or eye strain, in DES relates to the process of fixing the glance while using a computer terminal or otherwise screen-enabled device for a long period of time. Asthenopia in the past has been used as an all-encompassing term for DES symptoms, however it is now limited to the subjective feeling of discomfort stemming from convergence insufficiency during prolonged screen time. The subjective feeling of eye strain is attributed to the presence of changes in accommodative and vergence functions including exophoria, convergence insufficiency, low fusional convergence, decrease of accommodative amplitude and temporary myopic shift. Changes are transient, with no lasting impact after the subjects reduced their involvement with screens.

(b) Symptoms and signs related to dry eye syndrome.

Dry eye syndrome in DES is attributable to reduced blink rate and increased exposure of the eye due to horizontal gaze, which are both common during prolonged screen viewing.

(c) Symptoms and signs attributed to preexisting, inadequately treated, eye conditions (eg, refractive disorders, presbyopia, amblyopic eye).

Those will lead to subjective discomfort in shorter period of exposure compared to unaffected individuals, but they are expected to diminish once the underlying issue is resolved.

(d) Symptoms and signs attributed to poor ergonomics.

These are musculoskeletal problems (muscle stiffness and pain of the shoulders, neck and back, also tension headaches) that are attributed to assuming body positions that generate tension for a prolonged period of time, either in a work environment or outside work. The home environment is not regulated to professional standards and there is the added burden of using a handheld device, typically not at a desk.

There is also a significant number of technical factors that play a role on the development of symptoms including: display quality, display refresh rate, display size, display readability and legibility, and ambient environmental lighting during use.

However, there is an open question as to the relative degree of importance of these variables on the severity of DES, particularly regarding asthenopia. A recent study[45] of DES patients for the prevalence of binocular and accommodative anomalies, to evaluate potential mechanisms for the benefit from +0.75D addition lens did not find an important role for binocular and accommodative anomalies, save for the rarer instances of patients who had an eso-fixation disparity on the near Mallett unit. A comparative study of smartphone users to users of virtual reality head-mounted displays (VR SHMD) following two hours of continuous use, found significant changes in near-point convergence and accommodation, exophoric deviation, stereopsis, and accommodative lag after the use of the VR SHMD but not after that of smartphones.[46] Given that the proximity of the eye to the VR SHMD units was minimal (50 mm to 65 mm) it would appear that the effect of using digital screens at the typical viewing distances could be negligible per se; this however does not denote that their additive effect in conjunction with other sources of ocular discomfort would not be clinically meaningful. Indeed, a comparative study of viewing a documentary movie via smartphone or tablet[47] showed a decrease in post-use near point accommodation and convergence, which was larger for smartphone use, yet the accommodative response induced by dynamic accommodative stimulus of auto refractometer/keratometer did not change significantly post-use. The subjects reported more subjective discomfort after smartphone use, even when use time was shorter. Apparently, the eye discomfort may be only appreciable immediately after using the display, at least in adults. Reports, however, from the study of children and pre-teens found some evidence for an increase in convergence disorders following lengthy periods of online study during the COVID-19 epidemic; these included an increase in cases of acute acquired comitant esotropia[48] and an increase of mean near exophoria, negative fusional vergence and accommodation

amplitude,[49] following more than four hours of daily smartphone use. The examination of variables related to asthenopia could be more important in children.

Diagnostic Procedures for DES and Diagnostic Issues

Proposed diagnostic procedures relate to the four symptom categories (Table 1); clinicians should examine patients for the variables related to asthenopia and dry eye syndrome, they should ensure that no comorbid eye conditions are undetected or inadequately treated, while providing suggestions for better ergonomics during screen use. The examination of the accommodative and vergence functions would include standard procedures for the evaluation of ocular motility and squint,[50] examination of vergence insufficiency,[51] near point of accommodation, accommodative response and amplitude.[47] A multitude of new methods for the non-invasive diagnosis of dry eye syndrome are becoming available,[52] and are expected to help more than the less reliable or reproducible tear film break-up time test and Schirmer test. These include non-invasive tear breakup time, thermography, anterior segment optical coherence tomography, meibography, interferometry, in vivo confocal microscopy, and optical quality assessment. Refraction should be re-evaluated; small refractive errors may aggravate symptoms, while uncorrected presbyopia for adults over forty years of age could be first diagnosed during the examination for DES-related complaints. Posture-related symptoms are harder to assess outside a work environment and the advent of handheld screen-enabled devices has made this factor even harder to examine and control.[53] The patient could be instructed to measure a number of variables related to office ergonomics like the distance-to-screen and relative height of the line-of-eyesight and screen. However, other related parameters including relative angle to screen, ambient lighting and glare are hard to assess.

The use of diagnostic questionnaires for DES has been suggested by the American Academy of Ophthalmology for evaluating the severity of the syndrome.[4] A number of questionnaires are now available, including the Visual Fatigue Questionnaire,[54] the CVS questionnaire (CVS-Q),[55] the Computer Vision Symptom Scale (CVSS17)[56] and the Digital Eye Strain Questionnaire (DESQ).[57] All questionnaires attempt to cover the range of symptoms and may include either individual subfactors, which cluster groups of related symptoms[57] or attempt to measure the severity of individual symptoms.[55,56] All such questionnaires attempt to assess subjective discomfort and not objective eyesight parameters, thus any wide-arching conclusion on the objective burden of DES on the patient's eyesight should be discouraged. Furthermore, the question that was raised above, of the relative importance of symptoms in the severity of DES, is not addressed in any questionnaire. Hence, a false outcome of more or less severe impediment for the patient may be formed on the basis of these self-report questionnaires, since the effect of a small number of more severe manifestations may be equalized with a larger number of less severe ones in a total unweighted score. Also, since the symptoms fall into any one of the four different domains that were described above, it is unclear whether they may affect one another and to which extent, or whether they may be ordered in a clear time sequence. Their use would be of help in large-scale screening for the syndrome symptoms and an individual follow-up on the response following treatment.

Prevention and Management of DES

There is consensus on all reviews that management of DES is dependent on the results from the diagnostic procedures and underlying disorders; the existence of asthenopia, dry eye syndrome, any uncorrected visual issues, or poor ergonomics should be addressed according to established professional guidelines. However, prevention is key, since on the one hand all symptoms are potentially avoidable to a significant extent and on the other hand treating the symptoms without resolving their root causes will lead to a relapse. All sets of existing guidelines on DES[4–7] offer such guidance on DES prevention, although the framing is problematic and the average reader needs to skim through the entire publication and cherry-pick the relevant information. Separate sets of guidelines for the workplace, daily use of different handheld devices and for the parents of underage children would be ideal. Material in a printable hand-out form that the professional can have available in the consultation office would be helpful. Furthermore, there is little experimental evidence to confirm the effectiveness of a number of proposed treatments. Such an example is the proposed use of blue-light blocking glasses. LED screens and lighting have an intense emission in the blue wavelength, linked with retinal damage in experimental models[58] and circadian rhythm disruption. The use of glasses that selectively block this wavelength has been suggested as a protective measure against DES symptoms,[5] yet recent randomized studies have disputed this claim.[59,60] Various manufacturers have claimed that their specially designed products reduce focusing efforts while looking at computer screens, and although using these products has been suggested as a potential optical

Table 2 Management and Prevention of DES

Symptom Categories	Prevention	Management
Asthenopia symptoms	Public education on dangers from prolonged screen use. Periodical assessment with appropriate questionnaires at the workplace	Guidance on taking regular brakes from screen viewing and alternating close to long distance viewing
Dry eye symptoms	Contact lens users should be alerted to higher possibility of dry eye symptoms. Maintaining air quality in close environments where screen viewing takes place (maintaining appropriate humidity and a smoke-free space where screen use takes place). Placing a fixed screen below eye level. Maintaining eyelid hygiene. Periodical assessment with appropriate questionnaires at the workplace.	Lubricating eye drops, blinking exercises, regularly cleaning eyelids, correction of air quality and screen position if appropriate
Symptoms of other eye conditions	Periodical vision assessment of school children and computer users in the workplace. Provision of spectacles to correct small refractive errors in pre-presbyopic employees. Prescription of bifocals, varifocals or degressive lenses if the patient has to carry out a variety of tasks in the workplace	Correction of any existing eyesight issues and provision of appropriate lenses as suggested in the prevention section
Poor ergonomics	On-site assessment of ergonomics at work or patient's detailed description in a routine eye exam, dissemination of information to the lay public via social media and at school	Correction of office ergonomics and guidance for better viewing practices at home

aid,[6] there are no experimental data in peer-reviewed publications to back it up. A list of suggestions regarding prevention and management of DES is presented in Table 2.

Conclusion

Although there is a wealth of relevant studies, reviews and proposed guidelines available for DES, information for the lay public has not been filtered down to an easily accessible and clear format, while information for the professional may include suggestions, which remain unconfirmed, or even scientifically debunked. The need for standardization in proposed prevention and management strategies initially stemmed from the workplace; however, an additional challenge brought about by the introduction and dominance of screen-enabled handheld devices has emerged. Head mounted displays are slowly creeping into the living room and an increased uptake of technology related to virtual reality in the near future will mean that near-field vision will further increase the importance of addressing DES.

Disclosure

The authors have no competing interests to disclose.

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