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REVIEW PAPER

Prolonged screen-time as the cause of ocular disorders: what can we do with the problem? – a review

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ABSTRACT

Introduction and aim. Recently, an increased use of video display terminals has been observed in workplace environments, as a result of the evolution of communication technologies and new information-sharing strategies. It has led to an increased prevalence of computer-related ocular disorders, such as computer vision syndrome, dry eye disease, refractive errors and convergence insufficiency. In this review we describe problems associated with these disorders and propose preventive methods.
Material and methods. With the use of specific keywords, the databases of the PubMed, Science Direct, and Google Scholar were searched for relevant original papers.
Analysis of the literature. The listed disorders might have similar symptoms, such as eye burning, itching, blurred vision, and tearing, and their severity correlates with the time of exposure to video display units. However, there are preventive measures, which can help in decreasing the negative effects of computers on our vision, such as adequate viewing distance, proper workspace lighting, eyeglasses with anti-glare coating, taking 5-minutes breaks after every 30 minutes, or following the 20-20-20 rule.
Conclusion. Prolonged usage of the video display terminals is connected to many ocular disorders, and in today's world, it is very important to remember actions that can be undertaken to minimize the risk.
Keywords. computer vision syndrome, convergence insufficiency, eye strain, prolonged screen time, refractive errors, video display terminals

Introduction

Recently, an increased use of video display terminals (VDTs) has been observed in workplace environments as a result of the evolution of communication technologies and new information-sharing strategies.[1] According to the Sixth European Working Conditions Survey, more than half of the citizens of Europe use VDTs at work. It is mostly used in financial services and public administration, but the number of workers using VDTs in other sectors, e.g. health, construction, or agriculture, is still rising.[2] Nowadays, it is required to use smartphones, computers, tablet computers as well as electronic book readers in any location, not only at home or in the workplace.[3] Especially during the SARS-CoV-2 pandemic, many employees had been forced to start teleworking.[4] The actual time spent using electronic devices during the lockdown

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increased by 3.1±2.2 h/d or even 4.8 ± 2.8 h/d.[5,5] In addition, more than 60% of people reported a prolongation of screen time due to work or leisure.[6] Computer usage for relaxation is likely to occur during nighttime and thus can be associated with sleep problems.[7] Using social media is a major activity in the current world for emerging adults – over half of young adults spend 61-70 min/day on social networking sites and access social media multiple times a day.[9,8] Moreover, the pandemic has imposed other lifestyle changes, e.g., increased sedentary time and decreased physical activity.[9] Dietary problems and reduced exposure to sunlight can also be observed, predisposing to vitamin deficiency.[10] All of the listed changes in behavior, especially the prolonged screen time, are associated with visual and ocular discomfort.[11] The most common transformations connected to the increased use of VDTs are summed beneath (Table 1). In this review, we would like to present the most popular ocular issues related to computer work and emphasize the meaning of appropriate vision hygiene in the modern day.

Table 1. The main changes in people working with VDTs

Human body system	Change
External ocular	redness[12] increased tears evaporation[13]
Internal ocular	inflammatory changes of the eye[14] changed shape of the eye[15]
Visual	double vision[16] blurred vision[12] convergence change[17]
Oculomotor	reduced blink rate[14]
Musculoskeletal	posture change[18] muscle pain in the neck and shoulders[16]

Aim

This review aims to emphasize the problem of eye disorders connected to prolonged usage of screen devices by analyzing the results of clinical trials. In addition, through a critical assessment of available data, we present an analysis of the possible methods to prevent these changes.

Material and methods

For this narrative review, the keywords "computer vision syndrome," "uncorrected refractive errors," "convergence insufficiency," "dry eye disease," and "visual display terminal" were used to search PubMed, Science Direct, and Google Scholar databases. The search was conducted from December 21st, 2021, through June 13th, 2022. Only original papers, published in Polish or English that discussed the outcomes of clinical trials were taken into consideration. Papers deemed pertinent by the authors were included in the analysis. Manuscripts unrelated to the subject were excluded. All articles that met the review paper's criteria were included in the "result" segment. The quality assessment scale for narrative review articles (SANRA) has been applied to the construction of this narrative review.

Analysis of the literature

Computer vision syndrome

Computer vision syndrome (CVS) is becoming a growing public health issue.[19] Especially recently, in the times of online work and education, the scale of the problem grew to a much larger extent.[20] Computers and other electronic devices have become an integral part of everyday life.[21] People who are using computers and handheld electronic devices not only at work but also for leisure activities are more likely to develop CVS compared with people who use electronics in the work area only.[22] The other names for CVS are Digital Eye Strain or Visual Fatigue, which refer to a wider range of devices that can cause eye problems linked to the described condition.[23] Computer vision syndrome is a collection of visual, ocular, and musculoskeletal symptoms caused by prolonged use of computer displays or other electronic devices.[16] Symptoms are classified into internal ocular symptoms (strain, ache), external ocular symptoms (dryness, irritation, and burning), visual (blurred, double vision), and musculoskeletal (neck, shoulder, and back pain).[16] Eye burning, itching, blurred vision, and tearing are the most often reported symptoms.[24] Besides eye symptoms, one of the most common problems in people with CVS is headaches.[18,25] The severity and specific type of symptom depend on the time of exposure, environmental factors, and individual visual abilities.

Words and images on computer screens are created by combinations of tiny points called pixels, which makes it difficult for the human eye to maintain focus.[19] The use of computers causes tear evaporation, which leads to a reduction in the number of blinks and an incomplete eyelid closure.[13] The discomfort caused by the use of electronic devices has not yet been known to cause permanent damage, but it may negatively influence work productivity and the quality of life.[26] It is reported that nearly 60 million people suffer from CVS globally and that there are a million new cases each year.[27]

Many risk factors may be associated with the occurrence of symptoms of CVS. They can be divided into modifiable and unmodifiable risk factors, presented in table 2 (Table 2).

Table 2. CVS risk factors

Unmodifiable risk factors	Modifiable risk factors
age of the patient[24]	time spent on the near work[27]
sex[26]	size of the written text[28]
occurrence of the refractive error[29]	contrast of a bad quality[28]
dysfunction of the Meibomian gland[30]	distance from the monitor[31]
	lighting in the workplace[16]
	using contact lenses[32]
	air humidity in the workplace[33]
	using anti-glare screens[25]
	nicotine addiction[34]

Unmodifiable risk factors

The prevalence of computer dry eye differs with age.[35] There is a higher incidence of CVS in older patients,[27] although, children and adolescents might be at higher risk of developing computer vision syndrome in the COVID era due to excessive use of electronic devices.[36]

The prevalence of dry eye is higher in women than in men.[37] The difference might be caused by differences in the way that hormonal profiles changes with age between men and women.[38] A study showed that older women working with computers during the workday may be more vulnerable to computer eye dryness compared to nonuser women.[39] Significantly higher Ocular Surface Disease Index scores were observed in females.[40]

Uncorrected or under-corrected refractive error and binocular vision can predispose to CVS.[29] Even a small amount of refractive error of myopia, hyperopia, or astigmatism can increase discomfort with computer use.[41] Presbyopia has been identified with a high incidence of asthenopia.[23] Therefore, appropriate refractive correction is crucial to reduce symptoms of CVS. Moreover, Meibomian gland dysfunction and long screen exposure may influence the severity of symptoms.[30]

Modifiable risk factors

Risks that can be modified include the amount of time spent in front of the computer, using a humidifier, wearing contact lenses, increased psychological stress, and ergonomic practices.

Time spent in front of a computer plays a crucial role in developing symptoms of CVS.[27] A recent study concluded that the prevalence of CVS among students was much higher during the COVID-19 pandemic due to online classes.[42] The most common reported symptoms were: eye strain, headaches, blurred vision, heaviness, and redness of the eyes.[12] Long-term use of computers causes instability in the distribution of tears on the ocular surface which leads to increased evaporation of tears.[43] Tear film break-up time (TBUT) is the main measurement showing the effects of long computer use and TBUT values are significantly lower in groups of people using a computer and in the morning hours.[43]

Studies have shown that poor quality of the text, small font size, and low contrast can all contribute to the greater severity of dry eye.[28] Closer viewing distances strain the accommodation and vergence systems.[31] The height and tilt of the visual display, which can lead to musculoskeletal symptoms, should be optimized in the workplace.[44] Improper lighting such as the presence of glares and reflections on the screen can also lead to visual discomfort.[16] Studies prove that a natural source of light in the workplace lowers the risk of developing CVS compared to using a fluorescent bulb.[45] One study showed that workers who wear contact lenses and are exposed to the computer for more than 6 hours a day are more likely to suffer from computer dry eye than non-wearers working the computer for the same amount of time.[32] Contact lens wear is a major cause of tear film instability and dry-eye symptoms leading to end-of-the-day discomfort. Symptoms of CVS are exacerbated by longer wearing time, demanding visual tasks, and by dry environments. Ineffective cleaning of lenses may also play part in the occurrence of symptoms.[32] Low humidity conditions in the room have been shown to significantly affect tear stability in wearers of soft contact lenses which leads to a shortening of non-invasive tear break up time and thinner tear film.[46] Low-humidity rooms are recognized to exacerbate the severity of dry eye, especially in places where air-conditioning and central heating are used. A USB-powered desktop humidifier is proven to cause significant improvements in tear-film stability and can increase comfort during work in front of a monitor.[33] Some studies also suggest that symptoms of dry eye may be connected with increased psychological stress.[47] Nicotine use has also been found as a risk factor because cigarette smoke contains toxic substances and particles which can destabilize the tear film.[34]

Management of CVS

Ergonomic practices carry a significant impact on the occurrence of CVS. Taking frequent short breaks during work with a computer is considered the most effective preventive method that lowers the risk of developing computer dry eye.[48] Therapies that have been proposed to treat CVS include the use of lubricating drops which reduce tiredness, dryness, and difficulty focusing during computer use.[49] Taking Omega-3 supplements can alleviate dry eye symptoms and decrease tear evaporation in patients with CVS.[50] Blink training to increase the blink rate and adjustment of the humidity in the room are also worth considering.[3] Optimizing the workplace that uses computer displays is also crucial. Distance from the screen should be around 50 centimeters (40–75 cm) for large displays, e.g. laptops, computers, and for smartphones it is required to be at least 30 centimeters.[51,52] The top of the screen should be 10-20 degrees below eye level.[27] The use of higher frequency and higher resolution LED monitors, screen filters, and adjusting the ergonomic placement of the monitor can lower the symptoms of CVS.[41]

Uncorrected refractive errors

Uncorrected refractive error (URE) is a failure in focusing images on the retina, associated with the changed shape of the eye, which results in blurred vision.[53] It is the main reason for vision impairment (VI) and the second leading cause of blindness.[15,54] By 2050, the amount of people with VI or blindness (as a result of uncorrected refractive error) is expected to increase.[54] Three main types of URE are distinguished and involve: hyperopia and myopia which stand for spherical errors, and astigmatism, which is related to optical asymmetry.[55] The

prevalence of each type of URE is different in various world regions and it is in relation to age.[56] There might be an association between genetic factors and ethnic differences, but also the shared environments may differ with ethnicity.[55] The risk factors related to URE are female sex, family history, computer and smartphone usage, and near work e.g. reading, writing.[57-59] The studies show that myopia is the most common refractive error associated with screen time.[58-64] Regular use of a computer has 4.5 times higher impact on children than irregular use.[65] Furthermore, using VDTs for more than 6 hours/day increases the odds of myopia two times compared to using these devices for less than 2 hours/day.[66] There are also differences in age and the correlation between increased screen time and myopia – in children of 5 and 6 years old there is no association, but there is in children of 7 years old.[60] On the other hand, some of the studies do not show a statistically notable relation between computer work and myopia progression.[67,68] In addition, the bond between computer usage and myopia may not be meaningful when characterizing myopia as ≤−1.00 D and it indicates that the total amount of time spent on near work may not be as important as reading intensity.[66] It has also been shown that outdoor time decreases the prevalence.[56,58-60,62-64,69] The optimal time of outdoor activities requires more studies, but 2 hours per day may reduce the progression of myopia.[62] In addition, besides near computer work, reading may also increase the risk, even more than computer screens, but the effect can be limited by outdoor exercises.[59] Nowadays, even children are exposed to higher computer usage, due to homeschooling during the pandemic and the studies have shown a great impact of prolonged screen time on children's vision.[57-61,63,65] Moreover, some of the studies have demonstrated that watching television is not highly associated with expanded refractive error, while other ones have shown the relation.[70,71,57,62,64] To prevent changes, time spent on digital devices should be decreased to the minimum, there should be a rest for 10 minutes after 30–40 minutes of working and more time should be spent on outdoor activities.[62] Also, early screening for refractive error by eye examination has a significant impact.[54,69] The possibilities of treatment are eyeglasses, validated auto-refractors, and refractive surgery [laser *in situ* keratomileusis (LASIK)].[72]

Convergence insufficiency

Convergence insufficiency (CI) is a vision dysfunction in both eyes, represented by the inability to correctly converge or maintain precise convergence during concentrating on nearby objects.[17] Symptoms of this disorder contain diplopia, asthenopia, headaches, dizziness, and blurry vision.[73] The prevalence of CI is estimated around the range from 2.7% to 19.6% in children and adolescents.[74-77] It is a wide range of diversity and it is caused by different diagnostic criteria in the studies.[76] The main method to measure symptoms of CI is the convergence insufficiency symptom survey, which was designed in 1999.[78] The survey contains 15 questions about concentration during reading, words "jumping," pulling around eyes, etc., and the frequency of appearance.[79] It should not be used as a single tool to diagnose, but it is useful in controlling the therapy.[80] Another type of test to identify CI is the near point of convergence break (NPC) with a cut-point ≥6cm and it means the distance where there is reported diplopia or eye drifting out.[73,81] The leading issue connected to CI is near vision activity, which includes reading, drawing, video gaming, or using a computer, smartphone, etc.[17,78,82-84] Between digital devices, handheld electronics (smartphones, tablets) have the highest impact on CI, equivalent to reading.[82] Additionally, there are more negative symptoms during reading from smartphones and it might be associated with scrolling the text, which causes temporary loss of sharpness.[85] The studies show that after 60 minutes of reading on a smartphone the eyestrain symptoms escalate and it is correlated with closer viewing distance.[86] The eye disorders may also get worse during reading from VDTs in a dark room, particularly when the display brightness is high.[85] The impact of increased use of these utensils on CI is expressed as a change of NPC – after 4 hours of continuous computer gaming, it significantly rises.[84] However, even a short period of time (1h) of using the VDTs leads to an increased level of NPC.[87] The studies indicate that the time needed to return to the baseline may depend on the strength of VDTs work.[84] Nowadays, it may cause problems with performing duties in the office and also with learning for children.[88] Children with CI are more likely to declare struggle with schoolwork, and avoid reading due to disturbance.[89] The treatment of CI involves office-based vergence/accommodative therapy (the most effective), home-based pencil push-ups, home-based computer vergence/accommodative therapy, and prism glasses.[90,91] Vision therapy has a substantial role in improving binocular vision in the population of children with learning difficulties.[92] Moreover, conducting the screenings has a great impact on detecting people with this disorder and implementing the treatment.[81]

Dry eye disease

Dry eye disease (DED) is a chronic disorder of the ocular surface associated with a disturbance of tear producing and/or evaporation, which leads to the manifestation of discomfort and tear film instability, linked to increased tear osmolarity.[93] The main symptoms of DED are eye fatigue, sore eyes, irritation and itching of the eye, and a burning sensation.[11] Symptoms of DED are very similar to CVS symptoms – dry eye is the core manifestation of digital eye strain, but the CVS represents a wider spectrum

of vision-related and musculoskeletal dysfunctions.[14] There are two validated tests to assess the occurrence of dry eye, including the Dry Eye Questionnaire and the ocular surface disease index questionnaire.[94] The prevalence depends on the age and gender and rates from 2.7% in young people (18–45 years) up to 75% among older adults, especially women.[96,95] The risk factors connected to DED are female sex, autoimmune disorders, ophthalmic disorders, allergy and atopy, use of contact lenses, low physical activity, or increased use of electronic devices (smartphones, tablets).[95-101] There are several causes of the dry eye among VDTs users, including Meibomian gland dysfunction, decreased blink rate, and ocular surface inflammation.[102-104] The reduced blink incidence and insufficient blinks may cause increased tear evaporation.[105] Especially effort when reading influences the blink rate – it has been shown that reading in the extended display has a higher percentage of incomplete blinks than reading in the normal display.[105] Some of the studies also show the association between DED and blue light exposure, but none have been demonstrated *in vivo*.[14,109,110] Additionally, other work has presented that using blue-blocking filters has no validation.[106] There is no consensus on the impact on lacrimal gland functioning – some works suggest that increased time of using electronic devices might lead to aqueous deficiency, while others reveal normal lacrimal functioning.[100] Another risk factor for DED – low total physical activity is inversely related to the occurrence of dry eye, an extended time of sitting or using VDTs leads to increased DED prevalence.[98] All the listed factors may disrupt the homeostatic balance of the eye, which leads to tear instability and experiencing undesirable symptoms.[101] The treatment includes educational counseling, which helps with reducing modifiable risk factors, specialist anti-inflammatory medications, and controlling a diet high in Omega-3 fats, antioxidants and carotenoids.[94] Moreover, blinking exercises may increase the number of complete blinks, which improves the hydration of the ocular surface.[107]

Possible preventive measures for computer-related ocular disorders

As VDTs become an indispensable part of life, people search for ways to alleviate the impact of computers on our vision. Here, we assemble some recommendations with the potential to minimize the prevalence of computer-related ocular disorders (Table 3.).

The viewing distance for smartphone use should amount to over 30 centimeters and for larger display devices, such as computers or laptops, it should be extended to 40–75 centimeters. The angular size of the image resulting on the retina will be around 20 degrees, being consistent with the recommendations of the International Organization for Standardization and their requirements for electronic visual displays.[52,110] Some researchers, however, postulate that the distance for near work should be even greater, as reading from <30 cm is associated with the risk of myopia progression.[111]

Table 3. Preventive modifications

Unhealthy habits modifications	Environmental modifications
reduction of the time spent in front of the VDTs[62]	increasing the distance from the VDTs – around 30 cm for smartphones and 40–75 cm for computers[51]
adequate resting time – 5 minutes for every 30 minutes in front of the screen[108]	using the correct lightning during work[39]
increasing the time spent on outdoor activities[62]	putting the monitor below the eye level (15–20 degrees)[19]
blinking exercises[3]	placing VDTs on the side of the window, not in front[109]
using eye-drops[18]	
conducting screenings in the population[54]	

Proper lighting of the workspace should be ensured. Working with natural light has been shown to lower the risk of developing CVS, compared to workers using fluorescent bulbs.[45] When using artificial light, adjustable task lighting as an additional source of light was shown to increase musculoskeletal and visual comfort, as well as posture.[109,112]

Wearing computer eyeglasses or spectacles can lower the risk of CVS, probably due to the protective anti-glare coatings of the lens.[45] Blue-light filters, however, have been shown to decrease neither the symptoms of digital eye strain, nor eye dryness.[106,113,114] Screens of VDTs should emit circularly polarized light. In contrast to linear polarization, circular has been proven to decrease symptoms of asthenopia, eye dryness, and visual discomfort.[115]

Taking breaks during working with VDTs has a proven protective effect against eyestrain and muscle pain.[116] A proposed schedule to follow includes 30 minutes of work and 5 minutes of rest.[108] A different recommendation includes the 20-20-20 rule, which requires taking breaks after every 20 minutes of near-work and looking into a distance of at least 20 feet (6 meters) for 20 seconds.[117] Moreover, another study recommend a modified rule, 20-20-2, which to the classic one adds the encouragement to spend 2 hours/day outside.[118]

Conclusion

In an era where it is difficult to function without access to VDTs, it is very important to remember about actions we can undertake to minimize the negative effects of computers on our vision. Signs and symptoms of computer-related ocular disorders should not be ignored. Furthermore, patients ought to be educated on how to eliminate the risk factors for CVS development.

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Conflicts of interest

The authors declare no conflict of interest.

Data availability

Data supporting the results of this study shall, upon appropriate request, be available from the corresponding author.

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