Nutrition and Digital Eye Strain

Subjects: Ophthalmology

Contributor: Drake W. Lem , Dennis L. Gierhart , Pinakin Gunvant Davey

Digital eye strain is a complex, multifactorial condition that can be caused by excessive screen time exposure to various electronic devices such as smartphones, tablets, e-readers, and computers.

digital eye strain computer vision syndrome visual display terminal syndrome

1. Introduction

Digital Eye Strain is a multifactorial disease which encompass a large group of ocular and vision-related symptoms that can be attributed to prolonged and extended use of smartphones, tablets, e-readers, and computers [1][2]. In recent years, these electronic devices have become nearly ubiquitous in modern society and have given way to an ever-increasing global dependence upon their application across personal, educational, and occupational settings. While computers and smartphones may serve to enhance our daily lives and activities, the American Optometric Association found that as few as two hours of uninterrupted screen time exposure is sufficient for the onset of both ocular discomfort and vision-related problems to develop [2]. Long-term implications associated with digital eye strain have yet to be elucidated, however, a large body of evidence has already demonstrated an array of harmful physiological effects associated with greater time spent using digital display devices [3][4][5][6][7]. In lieu of this, one can safely predict the current global COVID-19 pandemic will further exacerbate the prevalence of digital eye strain into epidemic proportions affecting nearly all age groups.

In this digital era of increasing screen time habits, or time spent looking at these devices and omnipresent exposure, the incidence of screen-induced ocular health issues and visual discomfort will continue to present major public health issues [4][5][6]. Some reports estimate the overall prevalence may impact up to 90% of individuals in some populations making this an endemic problem that will require our utmost attention [6][8][9][10][11]. Recently, the Vision Council found that >80% of adults in the United States far exceeded the two hour minimum of daily use associated with greater risk for the onset of digital eye strain symptoms [2][12]. In fact, working-age adults are estimated to spend an average of seven hours daily using computers just for their profession [2], of which, roughly 60% reported experiencing symptoms of screen-induced visual stress [12]. As one would expect, similar habits are seen among children and adolescents wherein >70% regularly exceed two hours of daily exposure [12][13][14] and are more often using two or more devices simultaneously [15][16][17][18][19]. In consequence, multi-tasking with more than one electronic device often leads to further risk of developing symptoms and greater incidence of visual fatigue [6][12][20]. Moreover, several reports also show that both adults and adolescents routinely use smartphones and hand-held devices roughly one hour before going to sleep and immediately upon awakening in the morning [15][16][18][21][22].

While it is important to note, the physiological implications are not uniform across all electronic devices with digital display technology; for example, it appears there are distinguishable patterns between symptom profiles associated with the overuse of computers versus smartphones [3][16][22][23]. Hence, this may explain, at least in part, the high prevalence of digital eye strain amongst several types of individuals, including computer users [24][25], visual display terminal or "teleworkers" [3][26][27][28], technicians [29], university students and young adults [15][30][31][32][33][34][35][36], as well as children and adolescents [17][19][25][37][38][39][40][41][42][43]. Nonetheless, there is considerable evidence that substantiate the positive relationship between total amount of time spent using digital devices and overall risk of developing symptoms associated with digital eye strain [6][7][20][31][44][45].

1.1. Ocular and Vision-Related Symptoms

Traditionally, the effects of digital eye strain have been referred to interchangeably as computer vision syndrome (CVS) [1][2][32][46][47], as well as digital asthenopia [29][48], and vision display terminal (VDT) syndrome [3][24]. Commonly reported symptoms include eyestrain, eye soreness, headaches, blurred vision, diplopia, and dry eyes [4][5][6][8][46][49][50]. These ocular effects can be categorized according to: (1) external symptoms commonly associated with dry eye disease regarding changes in ocular surface homeostasis [2][15][49][51][52][53][54]; and (2) internal effects relating to aesthenopic symptoms and visual function impairment [6][8][24][55][56]. Although helpful, these distinctions are not mutually exclusive measures of disease etiology due to the subjective nature of visual sensory processing and high degree of variability among patient-reported symptoms. In consequence, the diagnostic parameters used to characterize digital eye strain often vary among available reports.

While the pathophysiology extends beyond the scope of the present review, it is important to briefly discuss the various contributing factors as they relate to the ability of nutrition in ameliorating symptoms associated with digital eye strain [6][44][49][57]. A number of excellent reviews which have discussed several putative mechanisms in more detail along with the spectrum of physiological effects can be found elsewhere [4][5][6][8][46][54][58][59].

1.1.1. Dry Eye Disease

Dry eye is among the most common ocular complaint reported by individuals with digital eye strain [9][51][52][60][61][62]. Symptoms often range from irritation, burning, and stinging, as well as epiphora and foreign body sensations [63][64]. It has been well-documented that greater screen time behaviors represent a major component in developing symptoms of dry eye, often associated with lacrimal gland dysfunction and signs of evaporative dry eye disease [3][27][44][58][60][61][62][65][66][67][68]. In particular, computer usage significantly influence various dynamics of blinking patterns (such as frequency, amplitude, and complete vs. incomplete) thereby further increasing the rate of evaporation and exacerbating tear film instability [18][23][54][58][68][69][70][71][72][73][74][75]. The combination of sub-optimal tear production and excessive evaporation can lead to tear hyperosmolarity with subsequent inflammation of the epithelial surface [76][77][78][79][80].

Dry eye-related symptoms of digital eye strain may also be attributed to meibomian gland dysfunction (MGD) [81][82][83][84][85][86][87][88][89]. Normal sebum production from these glands serves as an important role in preserving ocular surface homeostasis by regulating evaporation of the tear film. Furthermore normal secretion and movement of

meibomian glands depends on adequate blink dynamics, in fact, some reports indicate that dysfunction of meibomian glands may be responsible for triggering initial inflammatory response mechanisms in consequence of abnormal sebum production [82][84][85]. Furthermore, greater time spent using electronic devices have been shown to positively correlate with diagnostic parameters for MGD including meibum quality score, lipid margin abnormalities, and meibography gland drop out [88][89][90][91].

Moreover, it appears that a cascade of pro-inflammatory mechanisms which perturb homeostasis of the ocular surface are implicated in the onset of dry eye symptoms and ocular discomfort associated with digital eye strain. Among patients with dry eye disease, conjunctival and tear fluid samples provide indications of a pro-inflammatory condition marked by increased concentrations of late lipid peroxidation markers concomitant with reductions in endogenous antioxidant enzymes [92][93]. Early pathophysiology likely involves a vicious cycle between pro-oxidative and pro-inflammatory mechanisms which further contribute to worsening dysfunction of the ocular surface [49][59][66][67][81][93][94][95][96][97][98][99][100].

One school of thought suggests prolonged exposure to digital displays may serve an important role in exacerbating the extent of oxidative damage to various structures of the eye [59][88][89][101]. Peak spectral emission (visible blue light, 400–490 nm) from light-emitting diodes commonly used in digital display technology have been implicated with causing photo-oxidative damage to the outer retina, that is photoreceptors and retinal pigment epithelial cells [102][103]. It is known that short-wavelength (blue) light is of high energy and capable of proliferating reactive oxygen species (ROS) formation in a time-dependent manner [101][102]. Additionally, oxidative damage and apoptosis brought on by blue light irradiation within ocular surface tissues have been implicated with clinical manifestations of dry eye disease [59][88][89][104].

1.1.2. Asthenopia

With increasing screen time behavior, digital asthenopia (i.e., eye strain or fatigue) remains the most common visual complaint alongside blurred and double vision paired with headaches and ocular soreness [11][24][42][48][55][105][106][107][108]. Difficulty focusing between working distances can be attributed to accommodative and vergence-related stress in consequence of uncorrected refractive error or continuous fixation at close-viewing distances [6][8][24][55][56]. In comparison to reading printed text, using hand-held devices such as smartphones and tablets, impose a greater burden on ocular muscles leading to greater recession in near point of convergence and reductions in accommodative function [109][110][111][112]. In many cases, aesthenopic symptoms seem to emerge over time when the cognitive demands for a visual task overwhelm the individual's ability to perform them comfortably [1][2][31][34][113][114][115][116]. For instance, the visual demands of uninterrupted computer work can manifest as headaches and ocular discomfort due to glare and increased squinting.

1.2. Extraocular Symptoms

Often presenting as secondary perturbations that may arise in conjunction with vision-related symptoms, clinical manifestations of digital eye strain are not exclusive to the visual system tissue. For instance, office workers commonly report experiencing myofascial pain and discomfort in the neck, shoulders, and upper back regions [3][5]

[46][117]. Indications of musculoskeletal symptoms appear strongly associated with the postural demands of computer work, in addition to poor ergonomic practices and extended periods of physical inactivity [3][6][46][49][50][118][119].

On the other hand, greater use of hand-held electronic devices have also been associated with the preponderance of psychological disorders [43][120][121][122][123][124][125][126] and disruption in circadian rhythms [21][22][46][117][127][128][129]. It is well-documented that excessive screen time behaviors before bedtime may significantly alter the sleep-wake cycle which can lead to significant disturbances in sleeping patterns. Particularly among adolescents and younger adults, reports of digital eye strain are often associated with sleeping disorders such as insomnia and excessive daytime sleepiness [21][22][121][122][127][130][131]. Consequentially, chronic patterns of sleep loss and circadian misalignment ascribed with an evening chronotype are also linked to greater psychosocial stress paired with increased systemic markers of stress-related hormones [132][133][134][135]. Regular behaviors of excessive screen time activities among students are also strongly associated with greater risk of developing signs of anxiety and depression [120][123][124][126]. One school of thought suggests dry-eye related symptoms may help to explain, at least in part, some similarities observed between sleeping disorders and changes in mental health condition associated with overuse of hand-held devices in younger populations [68][123][136][137][138][139].

Moreover, chronic exposure to psychological stressors have been linked with triggering a pro-oxidative state throughout the body, and it appears that ameliorating systemic oxidative stress may considerably reduce measures of psychological stress as well [140]. Given the relationship between proper dietary behaviors and overall well-being, it is no surprise that regular consumption of nutraceuticals and foods rich in antioxidants (i.e., fresh fruits, leafy green vegetables, and fish) may offer protection against elements of biopsychosocial deterioration [141][142][143][144][145].

Nutraceuticals are dietary supplements that have greater amounts of nutrients that are naturally present in nature and consumed by individuals as routine part of diet. The nutraceuticals are pharmaceutical-grade supplements that have the potential of modulating disease pathways or disease state. Thus, further reinforcing the potential therapeutic application for nutrition to ameliorate the purported systemic oxidative condition associated with digital eye strain. However, they can only be marketed to support the structure or function of the body and the label of the nutraceuticals or dietary supplements includes disclosure that they are not intended to diagnose, treat, cure, or prevent diseases and they are not evaluated by the Food and Drug Administration (FDA) in the US.

2. Omega-3 Fatty Acids

Given that a core etiopathogenic mechanism of dry eye-related symptoms involve a chronic pro-inflammatory state, research has been focused on investigating adjunctive nutraceutical strategies aimed at targeting this component of ocular surface dysfunction. Due to their inherent anti-inflammatory properties and immunomodulatory potential, considerable research has been focused on the role of omega-3 polyunsaturated fatty acids (PUFAs) [146][147][148][149][150][151][152]. By increasing dietary consumption of omega-3 fatty acids compared to omega-6 fatty acids, clinical reports have demonstrated some ability to regulate the body's inflammatory state by attenuating pro-

inflammatory mediators [146][148]. Omega-3 PUFAs also serve an important role in the prevention of chronic systemic conditions such as cardiovascular disease [152][153][154][155], in addition to exerting protective ocular effects against cataracts [156][157][158] and age-related macular degeneration (AMD) [159][160][161][162].

For the management of ocular surface symptoms in digital eye strain, the capacity for omega-3 fatty acids to offer clinical benefits against the underlying mechanisms of dry eye disease is supported by robust scientific evidence [76][146][147][148][150][152][163][164][165][166][167][168][169]. In randomized clinical trials, short-term dietary supplementation with omega-3 PUFAs demonstrated enhanced therapeutic benefits in patients with mild-to-moderate dry eye disease (**Table 1**) [170][171][172][173][174][175][176][177]. A systematic review and meta-analysis found that patients receiving omega-3 PUFAs saw significantly better improvements in tear evaporation, tear osmolarity, and severity of dry eye symptoms compared with placebo [151]. Odds ratio (OR) for improvements in tear break-up time (TBUT) were significantly greater among those in the active treatment groups (OR: 8.72; 95% CI: 4.73–16.09; $p < 0.001$) [151]. Multivariate analyses performed by separate meta-analyses seem to mirror these findings, wherein short-term supplementation was also associated with increased tear production and secretion from lacrimal glands (Schirmer's test scores; $p < 0.001$) [167][168]. Based on the available evidence from clinical trials in patients with dry eye disease, one can postulate that nutraceutical strategies involving omega-3 fatty acids would likely alleviate similar signs of ocular dysfunction brought on by prolonged digital device use. This would particularly be important for individuals that have sub-optimal tear film dynamics and predisposed to dry eye disease and involved in significant activities with digital devices.

Table 1. Characteristics of the randomized clinical trials using omega-3 PUFA.

Author (Year)	Participants	Duration	Interventions per Day	Results
Bhargava (2015) [171]	478 patients with CVS; aged (23.3 ± 4.7) years in India	3 months	360 mg EPA + 240 mg DHA; placebo	Significant improvements in TBUT, Schirmer scores, and DESS scores ($p < 0.01$, for all)
Bhargava (2016) [178]	266 patients with CVS; aged (2±9.4 ± 4.8) years in India	45 days	1440 mg EPA + 960 mg DHA; placebo	Significant improvements in TBUT ($p < 0.01$) and DESS scores ($p < 0.001$)
Deinema (2017) [172]	54 patients with mild/moderate DE; aged (42.6 ± 3.9) years in Australia	90 days	1000 mg EPA + 500 mg DHA (in fish oil); 945 mg EPA + 510 mg DHA (in krill oil); placebo	Marked reduction in tear osmolarity ($p < 0.001$) and improvements in tear film stability ($p < 0.05$)
Epitropoulos (2016) [173]	105 patients with DE & MGD; aged (56.8 ± 17) years in USA	12 weeks	1680 mg EPA + 560 mg DHA; "placebo" (3136 mg linoleic acid)	Statistically significant reduction in tear osmolarity, OSDI scores, and TBUT ($p < 0.01$, for all)
Kangari (2013) [170]	64 patients with DE; aged (61.2 ± 8.3)	1 month	360 mg EPA + 240 mg DHA; placebo	Remarkable improvements in TBUT ($p < 0.001$), Schirmer's

Author (Year)	Participants	Duration	Interventions per Day	Results
	years in USA			scores, and OSDI (both $p < 0.05$)
Korb (2015) [174]	26 patients with Evaporative DE; aged (41.7 ± 19.8) years in USA	3 months	1000 mg omega-3 PUFA; placebo	Mean OSDI scores improved (+55%) significantly from baseline ($p < 0.001$)
Macsai (2008) [175]	38 patients with MGD; aged (50.7 ± 9.1) years in USA	12 months	~3300 mg ALA (in flaxseed oil, 6 g); placebo	Significant improvements in meibum scores ($p = 0.003$), TBUT ($p = 0.002$), and omega-6 to omega-3 PUFA ratio in plasma and RBC (both $p < 0.05$)
Malhotra (2015) [176]	60 patients with moderate MGD; aged (53.3 ± 6.9) years in India	12 weeks	720 mg EPA + 480 mg DHA; placebo	Enhanced benefits in OSDI scores, TBUT, and CS ($p < 0.05$, for all)
Olenik (2017) [177]	61 patients with MGD; aged (mean 56) years in Spain	3 months	1050 mg DHA + 127 mg EPA + 90 mg DPA (1.2 g total); placebo	TBUT, mean OSDI scores, lipid margin inflammation improved significantly ($p < 0.05$, for all)

a similar
e studies
significant

improvements in objective measures of inherent tear film stability and subjective dry eye symptoms in as few as 45 days of supplementation [171][178]. Marked improvements in Nelson grading scores upon impression cytology seem to mirror these findings, providing further evidence of the nutraceutical benefits of omega-3 fatty acids to promote healing of the conjunctival epithelium [169][171][178]. Given that hyperosmotic stress plays an important role in causing damage to the ocular surface, these observations wherein short-term supplementation produced a profound normalization in tear tonicity represent clinically meaningful effects to improve the severity of dry eye [179][180]. Similarly, these improvements in tear film stability may also be attributed to the nutraceutical effect of omega-3 fatty acids on ameliorating signs of MGD [81][82][83][84][85][87]. Given the importance of sebum production in maintaining proper stability of the tear film layer, the potential for these micronutrients to improve meibum composition scores and meibomian gland secretions should not be overlooked [174][175][177]. It should be noted that greater aqueous tear production was also observed following three months of supplementation in patients with computer vision syndrome [171], consistent with reports in dry eye disease [151][167][168].

For treatment of digital eye strain, the growing number of preliminary reports offer promising clinical evidence substantiating the capacity for omega-3 fatty acids to ameliorate signs of ocular surface dysfunction and dry eye-related symptoms. However, it is important to acknowledge a recent systematic review and meta-analysis by Singh et al. [181] that concluded that there is low-certainty evidence of benefits of omega-3 supplementation on reduction of dry eye symptoms in individuals that are symptomatic computer users.

References

1. American Academy of Ophthalmology; Tripathy, K.; Chandrasekaran, P.R. Computer Vision Syndrome (Digital Eye Strain). Available online: https://eyewiki.aao.org/Computer_Vision_Syndrome_(Digital_Eye_Strain) (accessed on 20 September 2021).
2. American Optometric Association. Computer Vision Syndrome. Available online: https://www.aoa.org/healthy-eyes/eye-and-vision-conditions/computer-vision-syndrome?sso=y (accessed on 20 September 2021).
3. Parihar, J.K.; Jain, V.K.; Chaturvedi, P.; Kaushik, J.; Jain, G.; Parihar, A.K. Computer and visual display terminals (VDT) vision syndrome (CVDTS). Med. J. Armed Forces India 2016, 72, 270–276.
4. Blehm, C.; Vishnu, S.; Khattak, A.; Mitra, S.; Yee, R.W. Computer vision syndrome: A review. Surv. Ophthalmol. 2005, 50, 253–262.
5. Gowrisankaran, S.; Sheedy, J.E. Computer vision syndrome: A review. Work 2015, 52, 303–314.
6. Sheppard, A.L.; Wolffsohn, J.S. Digital eye strain: Prevalence, measurement and amelioration. BMJ Open Ophthalmol. 2018, 3, e000146.
7. Kushima, M.; Kojima, R.; Shinohara, R.; Horiuchi, S.; Otawa, S.; Ooka, T.; Akiyama, Y.; Miyake, K.; Yokomichi, H.; Yamagata, Z.; et al. Association Between Screen Time Exposure in Children at 1 Year of Age and Autism Spectrum Disorder at 3 Years of Age: The Japan Environment and Children's Study. JAMA Pediatr. 2022, 176, 384–391.
8. Coles-Brennan, C.; Sulley, A.; Young, G. Management of digital eye strain. Clin. Exp. Optom. 2019, 102, 18–29.
9. Hayes, J.R.; Sheedy, J.E.; Stelmack, J.A.; Heaney, C.A. Computer use, symptoms, and quality of life. Optom. Vis. Sci. 2007, 84, 738–744.
10. Tauste, A.; Ronda, E.; Molina, M.J.; Segui, M. Effect of contact lens use on Computer Vision Syndrome. Ophthalmic Physiol. Opt. 2016, 36, 112–119.
11. Xu, Y.; Deng, G.; Wang, W.; Xiong, S.; Xu, X. Correlation between handheld digital device use and asthenopia in Chinese college students: A Shanghai study. Acta Ophthalmol. 2019, 97, e442–e447.
12. The Vision Council Shines Light on Protecting Sight—And Health—In a Multi-Screen Era|The Vision Council. Available online: https://www.thevisioncouncil.org/blog/vision-council-shines-light-protecting-sight-and-health-multi-screen-era (accessed on 21 September 2021).
13. Aguilar-Farias, N.; Toledo-Vargas, M.; Miranda-Marquez, S.; Cortinez-O'Ryan, A.; Cristi-Montero, C.; Rodriguez-Rodriguez, F.; Martino-Fuentealba, P.; Okely, A.D.; Del Pozo Cruz, B. Sociodemographic Predictors of Changes in Physical Activity, Screen Time, and Sleep among

Toddlers and Preschoolers in Chile during the COVID-19 Pandemic. Int. J. Environ. Res. Public Health 2020, 18, 176.

14. Ozturk Eyimaya, A.; Yalcin Irmak, A. Relationship Between Parenting Practices and Children's Screen Time During the COVID-19 Pandemic in Turkey. J. Pediatr. Nurs. 2021, 56, 24–29.
15. Cartes, C.; Segovia, C.; Salinas-Toro, D.; Goya, C.; Alonso, M.J.; Lopez-Solis, R.; Zapata, C.; Cabezas, M.; Yanez, P.; Flores-Rodriguez, P.; et al. Dry Eye and Visual Display Terminal-Related Symptoms among University Students during the Coronavirus Disease Pandemic. Ophthalmic Epidemiol. 2021, 29, 245–251.
16. Kim, J.; Hwang, Y.; Kang, S.; Kim, M.; Kim, T.S.; Kim, J.; Seo, J.; Ahn, H.; Yoon, S.; Yun, J.P.; et al. Association between Exposure to Smartphones and Ocular Health in Adolescents. Ophthalmic Epidemiol. 2016, 23, 269–276.
17. Mohan, A.; Sen, P.; Shah, C.; Datt, K.; Jain, E. Binocular Accommodation and Vergence Dysfunction in Children Attending Online Classes During the COVID-19 Pandemic: Digital Eye Strain in Kids (DESK) Study-2. J. Pediatr. Ophthalmol. Strabismus 2021, 58, 224–231.
18. Moon, J.H.; Kim, K.W.; Moon, N.J. Smartphone use is a risk factor for pediatric dry eye disease according to region and age: A case control study. BMC Ophthalmol. 2016, 16, 188.
19. Mylona, I.; Deres, E.S.; Dere, G.S.; Tsinopoulos, I.; Glynatsis, M. The Impact of Internet and Videogaming Addiction on Adolescent Vision: A Review of the Literature. Front. Public Health 2020, 8, 63.
20. Alabdulkader, B. Effect of digital device use during COVID-19 on digital eye strain. Clin. Exp. Optom. 2021, 104, 698–704.
21. Antona, B.; Barrio, A.R.; Gasco, A.; Pinar, A.; Gonzalez-Perez, M.; Puell, M.C. Symptoms associated with reading from a smartphone in conditions of light and dark. Appl. Ergon. 2018, 68, 12–17.
22. Wood, B.; Rea, M.S.; Plitnick, B.; Figueiro, M.G. Light level and duration of exposure determine the impact of self-luminous tablets on melatonin suppression. Appl. Ergon. 2013, 44, 237–240.
23. Rosenfield, M.; Jahan, S.; Nunez, K.; Chan, K. Cognitive demand, digital screens and blink rate. Comput. Hum. Behav. 2015, 51, 403–406.
24. Vilela, M.A.; Pellanda, L.C.; Cesa, C.C.; Castagno, V.D. Asthenopia Prevalence and Risk Factors Associated with Professional Computer Use—A Systematic Review. Int. J. Adv. Med. Sci. 2015, 3, 51–60.
25. Long, J.; Cheung, R.; Duong, S.; Paynter, R.; Asper, L. Viewing distance and eyestrain symptoms with prolonged viewing of smartphones. Clin. Exp. Optom. 2017, 100, 133–137.

26. Lawrenson, J.G.; Hull, C.C.; Downie, L.E. The effect of blue-light blocking spectacle lenses on visual performance, macular health and the sleep-wake cycle: A systematic review of the literature. Ophthalmic Physiol. Opt. 2017, 37, 644–654.
27. Courtin, R.; Pereira, B.; Naughton, G.; Chamoux, A.; Chiambaretta, F.; Lanhers, C.; Dutheil, F. Prevalence of dry eye disease in visual display terminal workers: A systematic review and meta-analysis. BMJ Open 2016, 6, e009675.
28. Salinas-Toro, D.; Cartes, C.; Segovia, C.; Alonso, M.J.; Soberon, B.; Sepulveda, M.; Zapata, C.; Yanez, P.; Traipe, L.; Goya, C.; et al. High frequency of digital eye strain and dry eye disease in teleworkers during the coronavirus disease (2019) pandemic. Int. J. Occup. Saf. Ergon. 2021, 28, 1787–1792.
29. Chawla, A.; Lim, T.C.; Shikhare, S.N.; Munk, P.L.; Peh, W.C.G. Computer Vision Syndrome: Darkness Under the Shadow of Light. Can. Assoc. Radiol. J. 2019, 70, 5–9.
30. Al Rashidi, S.H.; Alhumaidan, H. Computer vision syndrome prevalence, knowledge and associated factors among Saudi Arabia University Students: Is it a serious problem? Int. J. Health Sci. 2017, 11, 17–19.
31. Logaraj, M.; Madhupriya, V.; Hegde, S. Computer vision syndrome and associated factors among medical and engineering students in chennai. Ann. Med. Health Sci. Res. 2014, 4, 179–185.
32. Mowatt, L.; Gordon, C.; Santosh, A.B.R.; Jones, T. Computer vision syndrome and ergonomic practices among undergraduate university students. Int. J. Clin. Pract. 2018, 72, e13035.
33. Iqbal, M.; El-Massry, A.; Elagouz, M.; Elzembely, H. Computer Vision Syndrome Survey among the Medical Students in Sohag University Hospital, Egypt. Ophthalmol. Res. Int. J. 2018, 8, 1–8.
34. Shantakumari, N.; Eldeeb, R.; Sreedharan, J.; Gopal, K. Computer use and vision-related problems among university students in ajman, United arab emirate. Ann. Med. Health Sci. Res. 2014, 4, 258–263.
35. Wang, L.; Wei, X.; Deng, Y. Computer Vision Syndrome During SARS-CoV-2 Outbreak in University Students: A Comparison Between Online Courses and Classroom Lectures. Front. Public Health 2021, 9, 696036.
36. Malik, N.; Raj, A.; Dhasmana, R.; Bahadur, H. Effect of Late Night Studying and Excessive Use of Video Display Terminals on the Ocular Health of Medical Undergraduate Students in A Tertiary Care Hospital. J. Clin. Exp. Ophthalmol. 2018, 9, 773.
37. Ichhpujani, P.; Singh, R.B.; Foulsham, W.; Thakur, S.; Lamba, A.S. Visual implications of digital device usage in school children: A cross-sectional study. BMC Ophthalmol. 2019, 19, 76.
38. Dadson, P.; Brown, T.; Stagnitti, K. Relationship between screen-time and hand function, play and sensory processing in children without disabilities aged 4-7 years: A exploratory study. Aust.

Occup. Ther. J. 2020, 67, 297–308.

39. Ishii, K.; Aoyagi, K.; Shibata, A.; Koohsari, M.J.; Carver, A.; Oka, K. Joint Associations of Leisure Screen Time and Physical Activity with Academic Performance in a Sample of Japanese Children. Int. J. Environ. Res. Public Health 2020, 17, 757.
40. Breen, R.; Pyper, S.; Rusk, Y.; Dockrell, S. An investigation of children's posture and discomfort during computer use. Ergonomics 2007, 50, 1582–1592.
41. Wang, J.; Li, M.; Zhu, D.; Cao, Y. Smartphone Overuse and Visual Impairment in Children and Young Adults: Systematic Review and Meta-Analysis. J. Med. Internet Res. 2020, 22, e21923.
42. Vilela, M.A.; Pellanda, L.C.; Fassa, A.G.; Castagno, V.D. Prevalence of asthenopia in children: A systematic review with meta-analysis. J. Pediatr. 2015, 91, 320–325.
43. Domingues-Montanari, S. Clinical and psychological effects of excessive screen time on children. J. Paediatr. Child. Health 2017, 53, 333–338.
44. Al Tawil, L.; Aldokhayel, S.; Zeitouni, L.; Qadoumi, T.; Hussein, S.; Ahamed, S.S. Prevalence of self-reported computer vision syndrome symptoms and its associated factors among university students. Eur. J. Ophthalmol. 2020, 30, 189–195.
45. Ye, Z.; Abe, Y.; Kusano, Y.; Takamura, N.; Eida, K.; Takemoto, T.; Aoyagi, K. The influence of visual display terminal use on the physical and mental conditions of administrative staff in Japan. J. Physiol. Anthr. 2007, 26, 69–73.
46. Rosenfield, M. Computer vision syndrome: A review of ocular causes and potential treatments. Ophthalmic Physiol. Opt. 2011, 31, 502–515.
47. Segui Mdel, M.; Cabrero-Garcia, J.; Crespo, A.; Verdu, J.; Ronda, E. A reliable and valid questionnaire was developed to measure computer vision syndrome at the workplace. J. Clin. Epidemiol. 2015, 68, 662–673.
48. Vaz, F.T.; Henriques, S.P.; Silva, D.S.; Roque, J.; Lopes, A.S.; Mota, M. Digital Asthenopia: Portuguese Group of Ergophthalmology Survey. Acta Med. Port. 2019, 32, 260–265.
49. Mehra, D.; Galor, A. Digital Screen Use and Dry Eye: A Review. Asia Pac. J. Ophthalmol. 2020, 9, 491–497.
50. Lem, D.W.; Davey, P.G. Tackle Digital Eye Strain. Available online: https://www.optometricmanagement.com/issues/2020/september-2020/tackle-digital-eye-strain (accessed on 20 August 2022).
51. Kim, D.J.; Lim, C.Y.; Gu, N.; Park, C.Y. Visual Fatigue Induced by Viewing a Tablet Computer with a High-resolution Display. Korean J. Ophthalmol. 2017, 31, 388–393.

52. Akkaya, S.; Atakan, T.; Acikalin, B.; Aksoy, S.; Ozkurt, Y. Effects of long-term computer use on eye dryness. North. Clin. Istanb. 2018, 5, 319–322.
53. Sanchez-Valerio, M.D.R.; Mohamed-Noriega, K.; Zamora-Ginez, I.; Baez Duarte, B.G.; Vallejo-Ruiz, V. Dry Eye Disease Association with Computer Exposure Time Among Subjects with Computer Vision Syndrome. Clin. Ophthalmol. 2020, 14, 4311–4317.
54. Portello, J.K.; Rosenfield, M.; Chu, C.A. Blink rate, incomplete blinks and computer vision syndrome. Optom. Vis. Sci. 2013, 90, 482–487.
55. Iribarren, R.; Fornaciari, A.; Hung, G.K. Effect of cumulative nearwork on accommodative facility and asthenopia. Int. Ophthalmol. 2001, 24, 205–212.
56. Jaiswal, S.; Asper, L.; Long, J.; Lee, A.; Harrison, K.; Golebiowski, B. Ocular and visual discomfort associated with smartphones, tablets and computers: What we do and do not know. Clin. Exp. Optom. 2019, 102, 463–477.
57. Lin, C.W.; Yeh, F.M.; Wu, B.W.; Yang, C.H. The effects of reflected glare and visual field lighting on computer vision syndrome. Clin. Exp. Optom. 2019, 102, 513–520.
58. Fjaervoll, K.; Fjaervoll, H.; Magno, M.; Noland, S.T.; Dartt, D.A.; Vehof, J.; Utheim, T.P. Review on the possible pathophysiological mechanisms underlying visual display terminal-associated dry eye disease. Acta Ophthalmol. 2022.
59. Seen, S.; Tong, L. Dry eye disease and oxidative stress. Acta Ophthalmol. 2018, 96, e412–e420.
60. Uchino, M.; Yokoi, N.; Uchino, Y.; Dogru, M.; Kawashima, M.; Komuro, A.; Sonomura, Y.; Kato, H.; Kinoshita, S.; Schaumberg, D.A.; et al. Prevalence of dry eye disease and its risk factors in visual display terminal users: The Osaka study. Am. J. Ophthalmol. 2013, 156, 759–766.
61. Kawashima, M.; Yamatsuji, M.; Yokoi, N.; Fukui, M.; Ichihashi, Y.; Kato, H.; Nishida, M.; Uchino, M.; Kinoshita, S.; Tsubota, K. Screening of dry eye disease in visual display terminal workers during occupational health examinations: The Moriguchi study. J. Occup. Health 2015, 57, 253–258.
62. Toomingas, A.; Hagberg, M.; Heiden, M.; Richter, H.; Westergren, K.E.; Tornqvist, E.W. Risk factors, incidence and persistence of symptoms from the eyes among professional computer users. Work 2014, 47, 291–301.
63. American Academy of Ophthalmology. What Is Dry Eye? Available online: https://www.aao.org/eye-health/diseases/what-is-dry-eye (accessed on 20 August 2022).
64. American Optometric Association. Dry Eye. Available online: https://www.aoa.org/healthy-eyes/eye-and-vision-conditions/dry-eye?sso=y (accessed on 20 August 2022).
65. Uchino, M.; Uchino, Y.; Dogru, M.; Kawashima, M.; Yokoi, N.; Komuro, A.; Sonomura, Y.; Kato, H.; Kinoshita, S.; Schaumberg, D.A.; et al. Dry eye disease and work productivity loss in visual

display users: The Osaka study. Am. J. Ophthalmol. 2014, 157, 294–300.

66. Uchino, Y.; Kawakita, T.; Miyazawa, M.; Ishii, T.; Onouchi, H.; Yasuda, K.; Ogawa, Y.; Shimmura, S.; Ishii, N.; Tsubota, K. Oxidative stress induced inflammation initiates functional decline of tear production. PLoS ONE 2012, 7, e45805.
67. The definition and classification of dry eye disease: Report of the Definition and Classification Subcommittee of the International Dry Eye WorkShop (2007). Ocul. Surf. 2007, 5, 75–92.
68. Chidi-Egboka, N.C.; Jalbert, I.; Golebiowski, B. Smartphone gaming induces dry eye symptoms and reduces blinking in school-aged children. Eye 2022, 1–8.
69. Argiles, M.; Cardona, G.; Perez-Cabre, E.; Rodriguez, M. Blink Rate and Incomplete Blinks in Six Different Controlled Hard-Copy and Electronic Reading Conditions. Invest. Ophthalmol. Vis. Sci. 2015, 56, 6679–6685.
70. Cardona, G.; Garcia, C.; Seres, C.; Vilaseca, M.; Gispets, J. Blink rate, blink amplitude, and tear film integrity during dynamic visual display terminal tasks. Curr. Eye Res. 2011, 36, 190–197.
71. Collins, M.J.; Iskander, D.R.; Saunders, A.; Hook, S.; Anthony, E.; Gillon, R. Blinking patterns and corneal staining. Eye Contact Lens 2006, 32, 287–293.
72. Doughty, M.J. Consideration of three types of spontaneous eyeblink activity in normal humans: During reading and video display terminal use, in primary gaze, and while in conversation. Optom. Vis. Sci. 2001, 78, 712–725.
73. Jie, Y.; Sella, R.; Feng, J.; Gomez, M.L.; Afshari, N.A. Evaluation of incomplete blinking as a measurement of dry eye disease. Ocul. Surf. 2019, 17, 440–446.
74. Tsubota, K.; Nakamori, K. Effects of ocular surface area and blink rate on tear dynamics. Arch. Ophthalmol. 1995, 113, 155–158.
75. Golebiowski, B.; Long, J.; Harrison, K.; Lee, A.; Chidi-Egboka, N.; Asper, L. Smartphone Use and Effects on Tear Film, Blinking and Binocular Vision. Curr. Eye Res. 2020, 45, 428–434.
76. Pellegrini, M.; Senni, C.; Bernabei, F.; Cicero, A.F.G.; Vagge, A.; Maestri, A.; Scorcia, V.; Giannaccare, G. The Role of Nutrition and Nutritional Supplements in Ocular Surface Diseases. Nutrients 2020, 12, 952.
77. Aragona, P.; Rolando, M. Towards a dynamic customised therapy for ocular surface dysfunctions. Br. J. Ophthalmol. 2013, 97, 955–960.
78. Albietz, J.M. Prevalence of dry eye subtypes in clinical optometry practice. Optom. Vis Sci. 2000, 77, 357–363.
79. Versura, P.; Cellini, M.; Torreggiani, A.; Profazio, V.; Bernabini, B.; Caramazza, R. Dryness symptoms, diagnostic protocol and therapeutic management: A report on 1,200 patients.

Ophthalmic Res. 2001, 33, 221–227.

80. Jacobi, C.; Jacobi, A.; Kruse, F.E.; Cursiefen, C. Tear film osmolarity measurements in dry eye disease using electrical impedance technology. Cornea 2011, 30, 1289–1292.
81. Baudouin, C.; Messmer, E.M.; Aragona, P.; Geerling, G.; Akova, Y.A.; Benitez-del-Castillo, J.; Boboridis, K.G.; Merayo-Lloves, J.; Rolando, M.; Labetoulle, M. Revisiting the vicious circle of dry eye disease: A focus on the pathophysiology of meibomian gland dysfunction. Br. J. Ophthalmol. 2016, 100, 300–306.
82. Bron, A.J.; Tiffany, J.M. The contribution of meibomian disease to dry eye. Ocul. Surf. 2004, 2, 149–165.
83. Butovich, I.A. Meibomian glands, meibum, and meibogenesis. Exp. Eye Res. 2017, 163, 2–16.
84. Foulks, G.N. The correlation between the tear film lipid layer and dry eye disease. Surv. Ophthalmol. 2007, 52, 369–374.
85. Foulks, G.N.; Bron, A.J. Meibomian gland dysfunction: A clinical scheme for description, diagnosis, classification, and grading. Ocul. Surf. 2003, 1, 107–126.
86. Nelson, J.D.; Shimazaki, J.; Benitez-del-Castillo, J.M.; Craig, J.P.; McCulley, J.P.; Den, S.; Foulks, G.N. The international workshop on meibomian gland dysfunction: Report of the definition and classification subcommittee. Investig. Ophthalmol. Vis. Sci. 2011, 52, 1930–1937.
87. Schaumberg, D.A.; Nichols, J.J.; Papas, E.B.; Tong, L.; Uchino, M.; Nichols, K.K. The international workshop on meibomian gland dysfunction: Report of the subcommittee on the epidemiology of, and associated risk factors for, MGD. Investig. Ophthalmol. Vis. Sci. 2011, 52, 1994–2005.
88. Lee, H.S.; Cui, L.; Li, Y.; Choi, J.S.; Choi, J.H.; Li, Z.; Kim, G.E.; Choi, W.; Yoon, K.C. Influence of Light Emitting Diode-Derived Blue Light Overexposure on Mouse Ocular Surface. PLoS ONE 2016, 11, e0161041.
89. Lee, J.B.; Kim, S.H.; Lee, S.C.; Kim, H.G.; Ahn, H.G.; Li, Z.; Yoon, K.C. Blue light-induced oxidative stress in human corneal epithelial cells: Protective effects of ethanol extracts of various medicinal plant mixtures. Investig. Ophthalmol. Vis. Sci. 2014, 55, 4119–4127.
90. Wu, H.; Wang, Y.; Dong, N.; Yang, F.; Lin, Z.; Shang, X.; Li, C. Meibomian gland dysfunction determines the severity of the dry eye conditions in visual display terminal workers. PLoS ONE 2014, 9, e105575.
91. Fenga, C.; Aragona, P.; Cacciola, A.; Spinella, R.; Di Nola, C.; Ferreri, F.; Rania, L. Meibomian gland dysfunction and ocular discomfort in video display terminal workers. Eye 2008, 22, 91–95.
92. Choi, W.; Lian, C.; Ying, L.; Kim, G.E.; You, I.C.; Park, S.H.; Yoon, K.C. Expression of Lipid Peroxidation Markers in the Tear Film and Ocular Surface of Patients with Non-Sjogren

Syndrome: Potential Biomarkers for Dry Eye Disease. Curr. Eye. Res. 2016, 41, 1143–1149.

93. Dogru, M.; Kojima, T.; Simsek, C.; Tsubota, K. Potential Role of Oxidative Stress in Ocular Surface Inflammation and Dry Eye Disease. Investig. Ophthalmol. Vis. Sci. 2018, 59, DES163–DES168.
94. Choi, J.H.; Li, Y.; Kim, S.H.; Jin, R.; Kim, Y.H.; Choi, W.; You, I.C.; Yoon, K.C. The influences of smartphone use on the status of the tear film and ocular surface. PLoS ONE 2018, 13, e0206541.
95. Mizoguchi, S.; Iwanishi, H.; Arita, R.; Shirai, K.; Sumioka, T.; Kokado, M.; Jester, J.V.; Saika, S. Ocular surface inflammation impairs structure and function of meibomian gland. Exp. Eye Res. 2017, 163, 78–84.
96. Valero-Vello, M.; Peris-Martinez, C.; Garcia-Medina, J.J.; Sanz-Gonzalez, S.M.; Ramirez, A.I.; Fernandez-Albarral, J.A.; Galarreta-Mira, D.; Zanon-Moreno, V.; Casaroli-Marano, R.P.; Pinazo-Duran, M.D. Searching for the Antioxidant, Anti-Inflammatory, and Neuroprotective Potential of Natural Food and Nutritional Supplements for Ocular Health in the Mediterranean Population. Foods 2021, 10, 1231.
97. Wei, Y.; Asbell, P.A. The core mechanism of dry eye disease is inflammation. Eye Contact Lens 2014, 40, 248–256.
98. Pflugfelder, S.C.; de Paiva, C.S.; Li, D.Q.; Stern, M.E. Epithelial-immune cell interaction in dry eye. Cornea 2008, 27 (Suppl. 1), S9–S11.
99. Pflugfelder, S.C.; Solomon, A.; Stern, M.E. The diagnosis and management of dry eye: A twenty-five-year review. Cornea 2000, 19, 644–649.
100. Solomon, A.; Dursun, D.; Liu, Z.; Xie, Y.; Macri, A.; Pflugfelder, S.C. Pro- and anti-inflammatory forms of interleukin-1 in the tear fluid and conjunctiva of patients with dry-eye disease. Investig. Ophthalmol. Vis. Sci. 2001, 42, 2283–2292.
101. Tosini, G.; Ferguson, I.; Tsubota, K. Effects of blue light on the circadian system and eye physiology. Mol. Vis. 2016, 22, 61–72.
102. Kuse, Y.; Ogawa, K.; Tsuruma, K.; Shimazawa, M.; Hara, H. Damage of photoreceptor-derived cells in culture induced by light emitting diode-derived blue light. Sci. Rep. 2014, 4, 5223.
103. Roehlecke, C.; Schaller, A.; Knels, L.; Funk, R.H. The influence of sublethal blue light exposure on human RPE cells. Mol. Vis. 2009, 15, 1929–1938.
104. Niwano, Y.; Iwasawa, A.; Tsubota, K.; Ayaki, M.; Negishi, K. Protective effects of blue light-blocking shades on phototoxicity in human ocular surface cells. BMJ Open Ophthalmol. 2019, 4, e000217.
105. Gowrisankaran, S.; Nahar, N.K.; Hayes, J.R.; Sheedy, J.E. Asthenopia and blink rate under visual and cognitive loads. Optom. Vis. Sci. 2012, 89, 97–104.

106. Hashemi, H.; Saatchi, M.; Yekta, A.; Ali, B.; Ostadimoghaddam, H.; Nabovati, P.; Aghamirsalim, M.; Khabazkhoob, M. High Prevalence of Asthenopia among a Population of University Students. J. Ophthalmic Vis. Res. 2019, 14, 474–482.

107. Sheedy, J.E.; Hayes, J.N.; Engle, J. Is all asthenopia the same? Optom. Vis. Sci. 2003, 80, 732–739.

108. Touma Sawaya, R.I.; El Meski, N.; Saba, J.B.; Lahoud, C.; Saab, L.; Haouili, M.; Shatila, M.; Aidibe, Z.; Musharrafieh, U. Asthenopia Among University Students: The Eye of the Digital Generation. J. Fam. Med. Prim. Care 2020, 9, 3921–3932.

109. Iwasaki, T.; Kurimoto, S. Eye-strain and changes in accommodation of the eye and in visual evoked potential following quantified visual load. Ergonomics 1988, 31, 1743–1751.

110. Murata, K.; Araki, S.; Kawakami, N.; Saito, Y.; Hino, E. Central nervous system effects and visual fatigue in VDT workers. Int. Arch. Occup. Environ. Health 1991, 63, 109–113.

111. Hue, J.E.; Rosenfield, M.; Saa, G. Reading from electronic devices versus hardcopy text. Work 2014, 47, 303–307.

112. Park, M.; Ahn, Y.J.; Kim, S.J.; You, J.; Park, K.E.; Kim, S.R. Changes in Accommodative Function of Young Adults in their Twenties following Smartphone Use. J. Korean Ophthalmic Opt. Soc. 2014, 19, 253–260.

113. Thorud, H.M.; Helland, M.; Aaras, A.; Kvikstad, T.M.; Lindberg, L.G.; Horgen, G. Eye-related pain induced by visually demanding computer work. Optom. Vis. Sci. 2012, 89, E452–E464.

114. Singh, H.; Tigga, M.J.; Khan, N. Prevention of ocular morbidity among medical students by prevalence assessment of asthenopia and its risk factors. J. Evid. Based Med. Healthc. 2016, 3, 532–536.

115. Jaschinski, W.; Konig, M.; Mekontso, T.M.; Ohlendorf, A.; Welscher, M. Computer vision syndrome in presbyopia and beginning presbyopia: Effects of spectacle lens type. Clin. Exp. Optom. 2015, 98, 228–233.

116. Noreen, K.; Batool, Z.; Fatima, T.; Zamir, T. Prevalence of Computer Vision Syndrome and Its Associated Risk Factors among Under Graduate Medical Students. Pak. J. Ophthalmol. 2016, 32, 140–146.

117. Patil, A.; Chaudhury, S.; Srivastava, S. Eyeing computer vision syndrome: Awareness, knowledge, and its impact on sleep quality among medical students. Ind. Psychiatry J. 2019, 28, 68–74.

118. Treaster, D.; Marras, W.S.; Burr, D.; Sheedy, J.E.; Hart, D. Myofascial trigger point development from visual and postural stressors during computer work. J. Electromyogr. Kinesiol. 2006, 16, 115–124.

119. Hoyle, J.A.; Marras, W.S.; Sheedy, J.E.; Hart, D.E. Effects of postural and visual stressors on myofascial trigger point development and motor unit rotation during computer work. J. Electromyogr. Kinesiol. 2011, 21, 41–48.
120. Bener, A.; Bhugra, D. Lifestyle and depressive risk factors associated with problematic internet use in adolescents in an Arabian Gulf culture. J. Addict. Med. 2013, 7, 236–242.
121. Jenaro, C.; Flores, N.; Gómez-Vela, M.; González-Gil, F.; Caballo, C. Problematic internet and cell-phone use: Psychological, behavioral, and health correlates. Addict. Res. Theory 2007, 15, 309–320.
122. Lam, L.T. Internet gaming addiction, problematic use of the internet, and sleep problems: A systematic review. Curr. Psychiatry Rep. 2014, 16, 444.
123. Tan, Y.; Chen, Y.; Lu, Y.; Li, L. Exploring Associations between Problematic Internet Use, Depressive Symptoms and Sleep Disturbance among Southern Chinese Adolescents. Int. J. Environ. Res. Public Health 2016, 13, 313.
124. Tonioni, F.; D'Alessandris, L.; Lai, C.; Martinelli, D.; Corvino, S.; Vasale, M.; Fanella, F.; Aceto, P.; Bria, P. Internet addiction: Hours spent online, behaviors and psychological symptoms. Gen. Hosp. Psychiatry 2012, 34, 80–87.
125. Trnka, R.; Martinkova, Z.; Tavel, P. An integrative review of coping related to problematic computer use in adolescence. Int. J. Public Health 2016, 61, 317–327.
126. Wu, X.; Tao, S.; Zhang, Y.; Zhang, S.; Tao, F. Low physical activity and high screen time can increase the risks of mental health problems and poor sleep quality among Chinese college students. PLoS ONE 2015, 10, e0119607.
127. Touitou, Y.; Touitou, D.; Reinberg, A. Disruption of adolescents' circadian clock: The vicious circle of media use, exposure to light at night, sleep loss and risk behaviors. J. Physiol. Paris 2016, 110, 467–479.
128. Chang, A.M.; Aeschbach, D.; Duffy, J.F.; Czeisler, C.A. Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness. Proc. Natl. Acad. Sci. USA 2015, 112, 1232–1237.
129. Duraccio, K.M.; Zaugg, K.K.; Blackburn, R.C.; Jensen, C.D. Does iPhone night shift mitigate negative effects of smartphone use on sleep outcomes in emerging adults? Sleep Health 2021, 7, 478–484.
130. Choi, K.; Son, H.; Park, M.; Han, J.; Kim, K.; Lee, B.; Gwak, H. Internet overuse and excessive daytime sleepiness in adolescents. Psychiatry Clin. Neurosci. 2009, 63, 455–462.
131. Buysse, D.J.; Reynolds, C.F., 3rd; Monk, T.H.; Berman, S.R.; Kupfer, D.J. The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. Psychiatry Res. 1989, 28,

193–213.

132. Akerstedt, T. Psychosocial stress and impaired sleep. Scand. J. Work Environ. Health 2006, 32, 493–501.
133. Lucassen, E.A.; Zhao, X.; Rother, K.I.; Mattingly, M.S.; Courville, A.B.; de Jonge, L.; Csako, G.; Cizza, G.; Sleep Extension Study, G. Evening chronotype is associated with changes in eating behavior, more sleep apnea, and increased stress hormones in short sleeping obese individuals. PLoS ONE 2013, 8, e56519.
134. Merikanto, I.; Kortesoja, L.; Benedict, C.; Chung, F.; Cedernaes, J.; Espie, C.A.; Morin, C.M.; Dauvilliers, Y.; Partinen, M.; De Gennaro, L.; et al. Evening-types show highest increase of sleep and mental health problems during the COVID-19 pandemic—Multinational study on 19,267 adults. Sleep 2021, 45, zsab216.
135. Thielmann, B.; Schierholz, R.S.; Bockelmann, I. Subjective and Objective Consequences of Stress in Subjects with Subjectively Different Sleep Quality-A Cross-Sectional Study. Int. J. Environ. Res. Public Health 2021, 18, 9990.
136. Manglick, M.; Rajaratnam, S.M.; Taffe, J.; Tonge, B.; Melvin, G. Persistent sleep disturbance is associated with treatment response in adolescents with depression. Aust. N. Z. J. Psychiatry 2013, 47, 556–563.
137. Cheung, T.; Yip, P.S. Depression, Anxiety and Symptoms of Stress among Hong Kong Nurses: A Cross-sectional Study. Int. J. Environ. Res. Public Health 2015, 12, 11072–11100.
138. Szakats, I.; Sebestyen, M.; Nemeth, J.; Birkas, E.; Purebl, G. The Role of Health Anxiety and Depressive Symptoms in Dry Eye Disease. Curr. Eye Res. 2016, 41, 1044–1049.
139. Han, S.B.; Yang, H.K.; Hyon, J.Y.; Wee, W.R. Association of dry eye disease with psychiatric or neurological disorders in elderly patients. Clin. Interv. Aging 2017, 12, 785–792.
140. Srivastava, R.; Batra, J. Oxidative stress and psychological functioning among medical students. Ind. Psychiatry J. 2014, 23, 127–133.
141. Long, S.J.; Benton, D. A double-blind trial of the effect of docosahexaenoic acid and vitamin and mineral supplementation on aggression, impulsivity, and stress. Hum. Psychopharmacol. 2013, 28, 238–247.
142. El Ansari, W.; Adetunji, H.; Oskrochi, R. Food and mental health: Relationship between food and perceived stress and depressive symptoms among university students in the United Kingdom. Cent. Eur. J. Public Health 2014, 22, 90–97.
143. Zellner, D.A.; Loaiza, S.; Gonzalez, Z.; Pita, J.; Morales, J.; Pecora, D.; Wolf, A. Food selection changes under stress. Physiol. Behav. 2006, 87, 789–793.

144. Glabska, D.; Guzek, D.; Groele, B.; Gutkowska, K. Fruit and Vegetable Intake and Mental Health in Adults: A Systematic Review. Nutrients 2020, 12, 115.
145. Meyer, B.J.; Kolanu, N.; Griffiths, D.A.; Grounds, B.; Howe, P.R.; Kreis, I.A. Food groups and fatty acids associated with self-reported depression: An analysis from the Australian National Nutrition and Health Surveys. Nutrition 2013, 29, 1042–1047.
146. Calder, P.C. N-3 polyunsaturated fatty acids and inflammation: From molecular biology to the clinic. Lipids 2003, 38, 343–352.
147. Gordon, W.C.; Bazan, N.G. Mediator lipidomics in ophthalmology: Targets for modulation in inflammation, neuroprotection and nerve regeneration. Curr. Eye Res. 2013, 38, 995–1005.
148. Hwang, D. Fatty acids and immune responses--a new perspective in searching for clues to mechanism. Annu. Rev. Nutr. 2000, 20, 431–456.
149. James, M.J.; Gibson, R.A.; Cleland, L.G. Dietary polyunsaturated fatty acids and inflammatory mediator production. Am. J. Clin. Nutr. 2000, 71, 343S–348S.
150. Thode, A.R.; Latkany, R.A. Current and Emerging Therapeutic Strategies for the Treatment of Meibomian Gland Dysfunction (MGD). Drugs 2015, 75, 1177–1185.
151. Al-Namaeh, M. A systematic review of the effect of omega-3 supplements on meibomian gland dysfunction. Ther. Adv. Ophthalmol. 2020, 12, 2515841420952188.
152. Wall, R.; Ross, R.P.; Fitzgerald, G.F.; Stanton, C. Fatty acids from fish: The anti-inflammatory potential of long-chain omega-3 fatty acids. Nutr. Rev. 2010, 68, 280–289.
153. Eckert, G.P.; Lipka, U.; Muller, W.E. Omega-3 fatty acids in neurodegenerative diseases: Focus on mitochondria. Prostaglandins Leukot. Essent. Fat. Acids 2013, 88, 105–114.
154. Cicero, A.F.; Reggi, A.; Parini, A.; Borghi, C. Application of polyunsaturated fatty acids in internal medicine: Beyond the established cardiovascular effects. Arch. Med. Sci. 2012, 8, 784–793.
155. Yessoufou, A.; Nekoua, M.P.; Gbankoto, A.; Mashalla, Y.; Moutairou, K. Beneficial effects of omega-3 polyunsaturated Fatty acids in gestational diabetes: Consequences in macrosomia and adulthood obesity. J. Diabetes Res. 2015, 2015, 731434.
156. Iwig, M.; Glaesser, D.; Fass, U.; Struck, H.G. Fatty acid cytotoxicity to human lens epithelial cells. Exp. Eye Res. 2004, 79, 689–704.
157. Lu, M.; Taylor, A.; Chylack, L.T., Jr.; Rogers, G.; Hankinson, S.E.; Willett, W.C.; Jacques, P.F. Dietary fat intake and early age-related lens opacities. Am. J. Clin. Nutr. 2005, 81, 773–779.
158. Jacques, P.F.; Taylor, A.; Moeller, S.; Hankinson, S.E.; Rogers, G.; Tung, W.; Ludovico, J.; Willett, W.C.; Chylack, L.T., Jr. Long-term nutrient intake and 5-year change in nuclear lens opacities. Arch. Ophthalmol. 2005, 123, 517–526.

159. Smith, W.; Mitchell, P.; Leeder, S.R. Dietary fat and fish intake and age-related maculopathy. Arch. Ophthalmol. 2000, 118, 401–404.

160. Robman, L.; Vu, H.; Hodge, A.; Tikellis, G.; Dimitrov, P.; McCarty, C.; Guymer, R. Dietary lutein, zeaxanthin, and fats and the progression of age-related macular degeneration. Can. J. Ophthalmol. 2007, 42, 720–726.

161. Seddon, J.M.; Cote, J.; Rosner, B. Progression of age-related macular degeneration: Association with dietary fat, transunsaturated fat, nuts, and fish intake. Arch. Ophthalmol. 2003, 121, 1728–1737.

162. Seddon, J.M.; George, S.; Rosner, B. Cigarette smoking, fish consumption, omega-3 fatty acid intake, and associations with age-related macular degeneration: The US Twin Study of Age-Related Macular Degeneration. Arch. Ophthalmol. 2006, 124, 995–1001.

163. Liu, Y.; Kam, W.R.; Sullivan, D.A. Influence of Omega 3 and 6 Fatty Acids on Human Meibomian Gland Epithelial Cells. Cornea 2016, 35, 1122–1126.

164. Qiao, J.; Yan, X. Emerging treatment options for meibomian gland dysfunction. Clin. Ophthalmol. 2013, 7, 1797–1803.

165. Ramprasath, V.R.; Eyal, I.; Zchut, S.; Jones, P.J. Enhanced increase of omega-3 index in healthy individuals with response to 4-week n-3 fatty acid supplementation from krill oil versus fish oil. Lipids Health Dis. 2013, 12, 178.

166. Chinnery, H.R.; Naranjo Golborne, C.; Downie, L.E. Omega-3 supplementation is neuroprotective to corneal nerves in dry eye disease: A pilot study. Ophthalmic Physiol. Opt. 2017, 37, 473–481.

167. Giannaccare, G.; Pellegrini, M.; Sebastiani, S.; Bernabei, F.; Roda, M.; Taroni, L.; Versura, P.; Campos, E.C. Efficacy of Omega-3 Fatty Acid Supplementation for Treatment of Dry Eye Disease: A Meta-Analysis of Randomized Clinical Trials. Cornea 2019, 38, 565–573.

168. Chi, S.C.; Tuan, H.I.; Kang, Y.N. Effects of Polyunsaturated Fatty Acids on Nonspecific Typical Dry Eye Disease: A Systematic Review and Meta-Analysis of Randomized Clinical Trials. Nutrients 2019, 11, 942.

169. Mulqueeny, S.; Davis, R.L.; Townsend, W.D.; Koffler, B.H. The ONIT Study–Ocular Nutrition Impact on Tear Film. Adv. Ophthalmol. Amp Vis. Syst. 2015, 2, 38.

170. Kangari, H.; Eftekhari, M.H.; Sardari, S.; Hashemi, H.; Salamzadeh, J.; Ghassemi-Broumand, M.; Khabazkhoob, M. Short-term consumption of oral omega-3 and dry eye syndrome. Ophthalmology 2013, 120, 2191–2196.

171. Bhargava, R.; Kumar, P.; Phogat, H.; Kaur, A.; Kumar, M. Oral omega-3 fatty acids treatment in computer vision syndrome related dry eye. Cont. Lens Anterior Eye 2015, 38, 206–210.

172. Deinema, L.A.; Vingrys, A.J.; Wong, C.Y.; Jackson, D.C.; Chinnery, H.R.; Downie, L.E. A Randomized, Double-Masked, Placebo-Controlled Clinical Trial of Two Forms of Omega-3 Supplements for Treating Dry Eye Disease. Ophthalmology 2017, 124, 43–52.
173. Epitropoulos, A.T.; Donnenfeld, E.D.; Shah, Z.A.; Holland, E.J.; Gross, M.; Faulkner, W.J.; Matossian, C.; Lane, S.S.; Toyos, M.; Bucci, F.A., Jr.; et al. Effect of Oral Re-esterified Omega-3 Nutritional Supplementation on Dry Eyes. Cornea 2016, 35, 1185–1191.
174. Korb, D.R.; Blackie, C.A.; Finnemore, V.M.; Douglass, T. Effect of using a combination of lid wipes, eye drops, and omega-3 supplements on meibomian gland functionality in patients with lipid deficient/evaporative dry eye. Cornea 2015, 34, 407–412.
175. Macsai, M.S. The role of omega-3 dietary supplementation in blepharitis and meibomian gland dysfunction (an AOS thesis). Trans. Am. Ophthalmol. Soc. 2008, 106, 336–356.
176. Malhotra, C.; Singh, S.; Chakma, P.; Jain, A.K. Effect of oral omega-3 Fatty Acid supplementation on contrast sensitivity in patients with moderate meibomian gland dysfunction: A prospective placebo-controlled study. Cornea 2015, 34, 637–643.
177. Olenik, A.; Jimenez-Alfaro, I.; Alejandre-Alba, N.; Mahillo-Fernandez, I. A randomized, double-masked study to evaluate the effect of omega-3 fatty acids supplementation in meibomian gland dysfunction. Clin. Interv. Aging 2013, 8, 1133–1138.
178. Bhargava, R.; Kumar, P.; Arora, Y. Short-Term Omega 3 Fatty Acids Treatment for Dry Eye in Young and Middle-Aged Visual Display Terminal Users. Eye Contact Lens 2016, 42, 231–236.
179. Tomlinson, A.; Khanal, S.; Ramaesh, K.; Diaper, C.; McFadyen, A. Tear film osmolarity: Determination of a referent for dry eye diagnosis. Investig. Ophthalmol. Vis. Sci. 2006, 47, 4309–4315.
180. Lemp, M.A.; Bron, A.J.; Baudouin, C.; Benitez Del Castillo, J.M.; Geffen, D.; Tauber, J.; Foulks, G.N.; Pepose, J.S.; Sullivan, B.D. Tear osmolarity in the diagnosis and management of dry eye disease. Am. J. Ophthalmol. 2011, 151, 792–798.e791.
181. Singh, S.; McGuinness, M.B.; Anderson, A.J.; Downie, L.E. Interventions for the management of computer vision syndrome: A systematic review and meta-analysis. Ophthalmology 2022, 129, 1192–1215.