ARTICLE IN PRESS

Contact Lens and Anterior Eye xxx (xxxx) xxx

Contents lists available at ScienceDirect

Contact Lens and Anterior Eye

journal homepage: www.elsevier.com/locate/clae

Digital eye strain and its impact on working adults in the UK and Ireland

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ARTICLE INFO

Keywords:
Digital eye strain
Computer vision syndrome
UK
Ireland

ABSTRACT

Clinical relevance: Digital eye strain (DES) is a condition encompassing visual and ocular symptoms that may arise due to the prolonged use of digital devices. The 2023 Tear Film Ocular Surface Lifestyle report defined DES as “the development or exacerbation of recurrent ocular symptoms and / or signs related specifically to digital device screen viewing”. Studies vary as to the prevalence of DES with some reporting values as low as 10 % and some reporting values over 90 %, however no study has examined the prevalence of DES in the UK or Ireland (UK&I).

Purpose: To determine the prevalence of DES amongst adults who work with digital devices in UK&I, their symptoms and ameliorative approaches taken by those affected.

Methods: A web-based survey of digital device users was conducted. Adults who used a device for at least 1 h per day for work purposes were eligible to participate. The questionnaire was designed to determine the prevalence of DES, daily device usage, musculoskeletal and ocular symptoms, how they manage their symptoms and eye care history.

Results: Based on a Computer Vision Syndrome Questionnaire score ≥ 6, the occurrence of DES was high at 62.6 %. The mean number of hours devices were used for was 9.7 h. Musculoskeletal symptoms were reported by 94.3 % of users and ocular symptoms by 89.5 % with symptoms most likely to occur with those working from home. 8.1 % of respondents considered their symptoms significant enough to affect their work.

Conclusion: This study provides a valuable insight into DES in digital device users in UK&I and is the first of its kind to be completed. It shows, that while the level of DES is high in device users, at 62.6 %, the actual effect or consequences of it on many does not appear to be significant.

1. Introduction

Digital eye strain (DES) is a condition encompassing visual and ocular symptoms that may arise due to the prolonged use of digital devices. The 2023 Tear Film Ocular Surface Lifestyle report defined DES as “the development or exacerbation of recurrent ocular symptoms and / or signs related specifically to digital device screen viewing”. The use of varied digital devices has become ubiquitous amongst all age groups in recent years. A range of studies [1–3] have shown a high incidence of DES (e.g., up to 50 % or more), however few studies have examined the impact of DES on those affected and the ameliorative steps taken to reduce symptoms. In addition, while a link between DES and dry eye symptoms has been shown [4,5], few studies have attempted to measure dry eye prevalence using a validated instrument in those affected by DES and determine if there is a relationship between age, gender and hours of use.

Since the onset of the global COVID-19 pandemic, studies have shown that the prevalence of this condition has increased, this would not be surprising given the extensive use of digital devices by people working from home (where workstations designed for comfortable computer use may not be available) and for carrying out personal tasks, such as home shopping for food and other essential items [6–8].

There is a paucity of UK and Ireland data for the occurrence of DES. A study of optometrists in this region [9] highlighted that most practitioners (88.9 %) felt DES was an important concern and reported high levels of confidence in discussing DES and management options with patients (91.4 %). Practitioner estimates of the prevalence of DES (median 25 %, IQR 10—50 %) were lower than most previously published reports. Studies have been done elsewhere, Portello *et al.* (2012) [1] researched DES in New York (USA) and found 40 % of subjects reported their eyes being tired at least half the time while 32 % reported dry eye and 31 % reported eye discomfort. Symptoms also varied with gender (being greater in females) and with ethnicity (being greater in Hispanics). In their Malaysian study, Reddy *et al.* (2013) [58] found 89.9 %

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https://doi.org/10.1016/j.clae.2024.102176
Received 2 April 2024; Received in revised form 29 April 2024; Accepted 30 April 2024

of university students had symptoms of DES with headache and eye strain being the most disturbing symptoms (19.7 % and 16.4 % respectively).They also reported that students who used devices for more than 2 h per day and students who wore spectacles experienced significantly more symptoms of DES. A study by Tesfa *et al.* (2019) [29] in Ethiopia found 75.6 % of university secretaries experienced DES. Participants who used devices for ≥ 6 h per day were three times more likely to have DES than those who used their devices for < 6 h per day. In their Indian study, Ahuja *et al.* (2021) [44] reported 62.4 % of computer users reported symptoms of DES.They also reported high levels of DES in spectacle wearers (78.1 %) and higher levels in males than females. Zayed *et al.* (2021) [31] in an Egypt based study found a DES prevalence of 82.41 % among information technology workers in Tanta University. The study found that female gender, age ≥ 35 years, daily computer use of ≥ 6 h and wearing spectacles were significant predictors of DES. As can be seen from these worldwide studies, DES prevalence rates can differ significantly as can the associated risk factors and symptoms. It is possible that DES prevalence, like dry eye, will differ between ethnic groups and between males and females [10]. At the time of writing, no similar study has been carried out in the UK or Ireland to determine if these populations will have similar or different findings to those carried out elsewhere in the world.

The aim of this study is to determine the prevalence of DES amongst adults who work with computers / digital devices in the UK and Ireland, the impact of their symptoms and ameliorative approaches taken by those affected.

Table 1
Summary of the 41-item questionnaire for adult digital device users in Ireland and the UK.

Section	Item numbers	Summarised questions
About you	1–3	Age Gender Ethnic group
Use of digital devices	4–7	Daily use of digital devices Working from home patterns Hours per day using devices Changes to level of device usage since the pandemic
Symptoms of DES, DEQ-5, CVS-Q, methods to relieve DES and self-reported DES	8-14a	Eye discomfort on a typical day and intensity. DEQ-5 Frequency of DES over the last month and intensity CVS-Q Methods to relieve DES symptoms Self-reported DES
Eye care and vision correction	14b-16	Time since last eye examination Expectations for DES management during the eye examination Vision correction used when using digital devices

2. Methods

The study received a favourable opinion from the Health and Life Sciences Research Ethics Committee at Aston University (#1769) and was conducted according to the tenets of the Declaration of Helsinki. A web-based survey of computer / digital device users in Ireland and the UK was conducted, following a pilot version to optimise the coverage and comprehension. Participation was voluntary, and before beginning the survey, respondents were required to indicate their consent after reading the participant information and transparency statement. The questionnaire was anonymous, although respondents had the option of providing their email address if they wished to be informed of the results of the study and / or enter a draw for one of five £50 vouchers for respondents who completed the survey in full.

2.1. Sample and Materials

Adults in Ireland and the UK who used a digital device for at least 1 h per day for work purposes were eligible to participate. The questionnaire was designed to determine the prevalence of digital eye strain in computer / digital device users in Ireland and the UK along with their daily digital device usage, musculoskeletal and ocular symptoms, how they manage their symptoms and eye care history. Sample size calculation is important in all aspects of research as using an adequate sample size will help in the collection of high quality data which is more reliable and valid for the cohort being studied [11]. An appropriate sample size renders the research more efficient, represents the population better and allows for confidence in conclusions drawn from the data [12,13]. With an estimated working age population of 34.75 million (32.5 million in UK and 2.25 million in Ireland) [14,15] across the two countries, the required sample size for a 95 % confidence interval and a ± 5 % margin of error would be 385 responses [16].

The questionnaire was hosted by *Online Surveys* (https://www.onlinesurveys.ac.uk/), a General Data Protection Regulation (GDPR) compliant platform designed for academic research. The survey included items in 5 key areas (a summary of the questionnaire is shown in Table 1. below). Following three initial items on respondent demographics (age, gender and ethnic group), the second part of the survey collected information regarding the respondent's use of digital devices, the types of devices used and duration of use. Respondents were asked if their use of digital devices had changed since the COVID-19 pandemic. It asked about symptoms of DES they may or may not experience and how they rank their symptom severity.

The next section of the survey included the 5 items from the validated Dry Eye Questionnaire (DEQ-5) [17]. While other questionnaires were considered, such as the OSDI and SPEED, the DEQ-5 was chosen due to its validity, simplicity and ease of completion. Based on a typical day in the last month, the participant is required to report how often their eyes felt discomfort or dryness and the intensity of the feeling (0–5 scale) within 2 h of going to bed. The fifth item links to eyes looking or feeling excessively watery. Possible scores range from 0 to 22; for screening purposes, it has been proposed that dry eye should be considered for scores > 6, scores > 12 indicate severe dry eye symptoms and possible Sjogren's syndrome [17]. The findings in the TFOS DEWS II report indicate dry eye can only be diagnosed when there are both symptoms and objective signs [18,19], so while a positive score for dry eye on the DEQ-5 cannot alone be used to diagnose dry eye, the DEQ-5 has been shown to be comparable to the Ocular Surface Disease Index (OSDI) in discriminating symptoms of dry eye and can be considered a valid means for assessing dry eye symptoms in both clinical and epidemiological studies [20].

Respondents also completed all items from the validated Rasch-analysed Computer Vision Syndrome Questionnaire (CVS-Q) designed to measure visual symptoms related to computer use in the workplace [21]. Respondents were further asked to indicate if they considered themselves to be affected by DES.

The final section of the survey questioned the device user about their eye care, such as time since last eye examination, use of visual correction while using digital devices and expectations of their eye examination for helping with DES.

Following initial development of the questionnaire by academic optometrists with research interests in DES and the ocular surface / dry eye, a pilot online survey of eligible respondents was undertaken to obtain feedback on the relevance and ease of understanding the survey. Participants in the pilot worked in various office settings, were gender and age balanced and, in so far as was possible, were from various ethnic groups. One change was made to the survey following this feedback, the participant information sheet (PIS) was shortened, however a hyperlink was available which the participant could click if they wished to get further information on the survey. None of the 23 pilot responses were included in the final analysis.

The survey was open for 15 weeks between October 2021 and January 2022. A request was made to Technological University Dublin (Ireland) and Aston University (UK) to distribute the survey to its workforce, 3500 [22] and 1165 [23] respectively. Smaller companies (local to the researcher's optometric practice) were also emailed to seek permission to distribute the survey. A significant response was achieved which allowed the researchers to exceed the minimum number of responses outlined above.

Following closure of the survey, data was exported into an Excel spreadsheet for analysis and cleaned. The survey was structured so that incomplete responses were not recorded. For the item involving free-text responses answers were coded and assigned to categories by a single investigator before being reviewed by a second investigator. Statistical analysis of the data using the Kolmogorov-Smirnov test (K-S) showed the data in this study was not normally distributed ($P < 0.001$) and as such non-parametric tests, such as Spearman's rank-order correlation coefficient and Mann-Whitney U test, were used to analyse the data.

3. Results

3.1. Profile of the respondents

Four hundred and fifteen responses were received in total; four responses were removed from the analysis as the respondents stated they did not use computers or digital devices frequently, another ten responses were removed as their responses were highly inconsistent across different sections of the survey. A total of 401 responses were included in the final analysis which exceeded the required sample size of 385. Of the respondents 255 were female (63.6 %), 140 were male (34.9 %), 2 (0.5 %) were non-binary, 3 (0.7 %) preferred not to say and 1 (0.2 %) chose to self-describe.

A breakdown of respondents ages is shown in Fig. 1 below. Based on age norms, 33.9 % were classified as pre-presbyopic (18–34 years), 19.2 % as nascent presbyopes (35–44 years) and 55.7 % were presbyopic (45 years and over) [24].

With respect to their ethnic group, 361 (90 %) identified as white, 23 (5.75 %) as Asian, 7 (1.75 %) as mixed race, 4 (1 %) as black, 1 (0.25 %) as Arab, 2 (0.5 %) as other, 2 (0.5 %) preferred not to say and 1 (0.25 %) chose to self-describe.

3.2. Respondents place of work

Ninety (22.4 %) did not work regularly from home, 76 (19 %) stated they worked up to 15 h per week at home, 104 (25.9 %) worked between 16 and 30 h per week at home and 131 (32.7 %) worked for more than 30 h per week at home.

3.3. Daily device type and usage

The device types that respondents said they used the most were smart phones followed by laptop computer, desktop computer, tablet and electronic 'e' reader.

A breakdown of device type and hours used is shown in Table 2. below.

Of the 401 responses, 318 (79.8 %) indicated their usage had increased since the start of the pandemic, 81 (20.2 %) said it had remained the same and only 2 (0.2 %) said it had decreased. Two hundred and sixty-one respondents (65.1 %) used digital devices for over 8 h per day and 31 (7.7 %) reported using devices for ≥ 16 h per day. The median number of hours for which devices were used was 9 (IQR 8–11). Spearman's rank-order correlation coefficient showed a weak negative relationship between age and hours per day of device use.

Table 2
Respondents digital device usage- type and daily duration (respondents could select multiple devices if applicable).

Daily duration (hours)			Device type used n (%)		
	Desktop	Laptop	Tablet	Smartphone	E reader
0	184 (45.9)	77 (19.2)	282(70.3)	18 (4.5)	348 (86.8)
0.5	12 (3)	16 (4)	30 (7.5)	35 (8.7)	21 (5.2)
1	20 (5)	29 (7.2)	43 (10.7)	94 (23.4)	22 (5.5)
2	22 (5.5)	24 (6)	29 (7.2)	121 (30.2)	7 (1.7)
3	17 (4.2)	20 (5)	9 (2.2)	70 (17.4)	0 (0)
4	17 (4.2)	33 (8.2)	6 (1.5)	29 (7.2)	2 (0.5)
5	24 (6)	27 (6.7)	0 (0)	10 (2.5)	0 (0)
6	26 (6.5)	44 (11)	1 (0.2)	10 (2.5)	0 (0)
7	31 (7.7)	33 (8.2)	1 (0.2)	4 (1)	0 (0)
8 h or more	48 (12)	98 (24.4)	0 (0)	10(2.5)	1 (0.2)

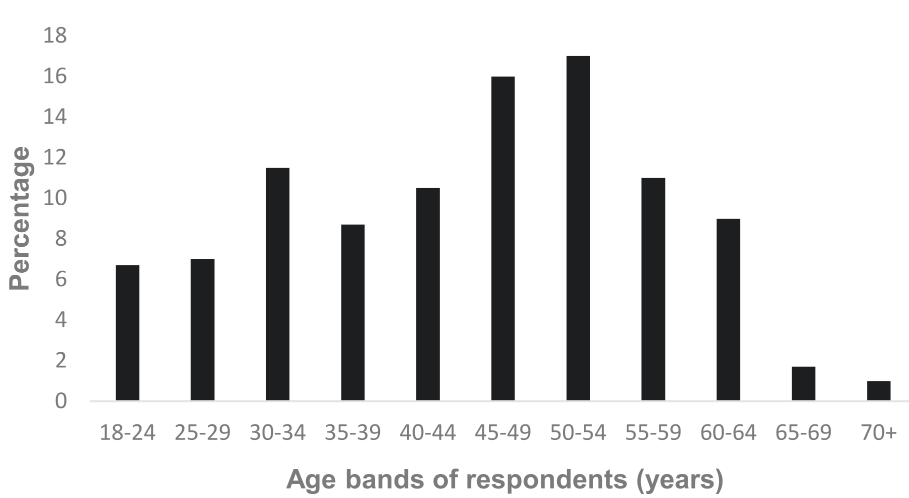

Fig. 1. Percentage age bands of respondents (n = 401).

(r_s = -0.165, r_s^2 = 0.02722, P = 0.001).

3.4. DEQ-5

The median DEQ-5 score was 8 (IQR 5–11), with a range of 0 to 21; 61.8 % of participants returned a score > 6, 66.4 % of females had a score > 6 and 52.1 % of males had a score > 6. The age band with the greatest number of results > 6 was 60–64 years, with 72.2 % of this band having a DEQ-5 result > 6, the age band with the lowest occurrence was the 70 years and above, with 50.0 % of this band having a DEQ-5 result > 6. Spearman's rank-order correlation coefficient showed no significant relationship between DEQ-5 and age (r_s = -0.00884, r_s^2 = 0.00007, P = 0.860), however hours per day of device use and DEQ-5 did show a weak positive relationship (r_s = 0.107, r_s^2 = 0.01145, P = 0.0324).

Females had a median DEQ-5 score of 9 (IQR 6–11), males had a median DEQ-5 score of 7 (IQR 4–10). A Mann-Whitney U test showed that the median DEQ-5 score was significantly higher in females than males (U = 14340.5; P = 0.003). Of respondents, 65.1 % said they experienced eye discomfort sometimes or frequently on a typical day, 6 % of respondents said it never occurred.

Regarding eye dryness, 51.2 % of respondents reported it occurring sometimes or frequently on a typical day in the last month, with only 19.0 % saying it never occurred. Thirty four percent of respondents said that their eyes looked or felt excessively watery sometimes or frequently on a typical day during the last month with 30.9 % saying they never did. Fig. 2 shows the breakdown of symptom prevalence reported by respondents when answering the DEQ-5 questionnaire.

Of the 311 participants who said they worked from home (either fully or partially), 61.7 % had a DEQ-5 score > 6 and of the participants over the age of 40, 61.5 % had a score > 6.

3.5. Computer vision syndrome questionnaire (CVS-Q)

Two hundred and fifty-one (62.6 %) respondents returned a score ≥ 6 for the CVS-Q, the median score being 7 (IQR 4–10), with a range of 0 to 25, 70.7 % of females had a score ≥ 6 and 47.14 % of males had a score ≥ 6.

The age band with the highest percentage of results ≥ 6 was 50–54 years, with 77.92 % of this band having a CVS-Q ≥ 6, the age band with the lowest percentage was the 65–69 years, with 28.6 % of this band having a CVS-Q ≥ 6. Spearman's rank-order correlation coefficient showed no significant relationship between CVS-Q and age (r_s = -0.00769, r_s^2 = 0.00005, P = 0.878), however hours per day of device use and CVS-Q did show a weak positive relationship (r_s = 0.155, r_s^2 = 0.024, P = 0.00183). Fig. 3 below shows the full breakdown by age band.

Females had a median CVS-Q score of 8 (IQR 5–11), males had a median CVS-Q score of 5 (IQR 2–9). A Mann-Whitney U test showed that the median CVS-Q score was significantly higher in females than males (U = 12182.6; P < 0.001).

The symptoms most commonly selected on the CVS-Q (as either 'occasionally' or 'often / always') were 'dryness' (n = 265, 66.3 %), 'headache' (n = 250, 62.3 %) and 'itching' (n = 244, 60.8 %). The three least commonly selected symptoms were 'double vision' (n = 57, 14.2 %), 'coloured halos around objects' (n = 92, 22.9 %) and 'burning' (n = 126, 31.4 %). A full breakdown of the frequency of symptom selected is shown in Fig. 4 below.

Of the 311 respondents who worked from home, 64.6 % had a CVS-Q score ≥ 6. When considering participants > 40 years (n = 265), 60 % had a CVS-Q score of ≥ 6. Of those who reported musculoskeletal symptoms (n = 378), 64 % had a score ≥ 6 and of those who reported ocular symptoms (n = 359), 68.5 % had a score ≥ 6.

When responses between the DEQ-5 and the CVS-Q questionnaires are analysed, the results are highly positively correlated with Spearman's rank-order correlation coefficient r_s = 0.60, r_s^2 = 0.36, P < 0.00001 (Fig. 5 below).

3.6. Musculoskeletal symptoms

378 (94.3 %) respondents reported symptoms such as neck, shoulder or back pain when using digital devices during the last month, with 50.1 % saying they occurred regularly (twice a week or more) or very frequently (most days), 30.7 % reported such symptoms occurring occasionally (approximately once a week).

Of the 378 who reported musculoskeletal symptoms, 64.4 % had a DEQ-5 score > 6 and 64 % had a CVS-Q score ≥ 6.. Spearman's rank-order correlation coefficient showed a significant relationship between DEQ-5 and musculoskeletal symptoms (r_s = 0.28491, r_s^2 = 0.08117, P < 0.00001) and CVS-Q and musculoskeletal symptoms (r_s = 0.43944, r_s^2 =

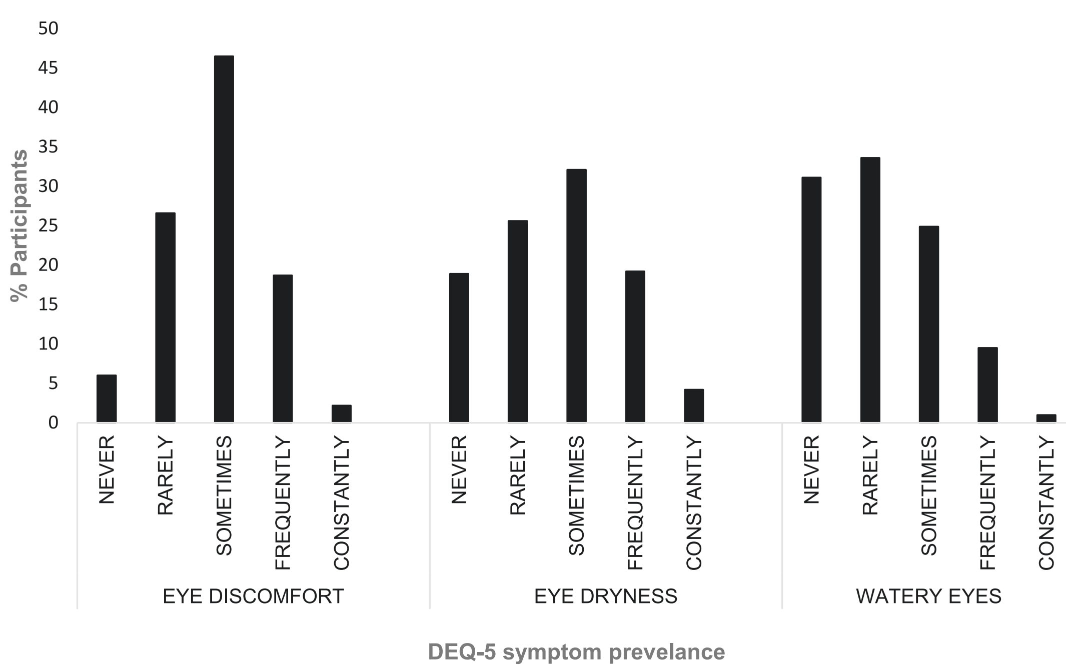

Fig. 2. Occurrence of symptoms as reported on the DEQ-5 questionnaire on a typical day during the last month (n = 401).

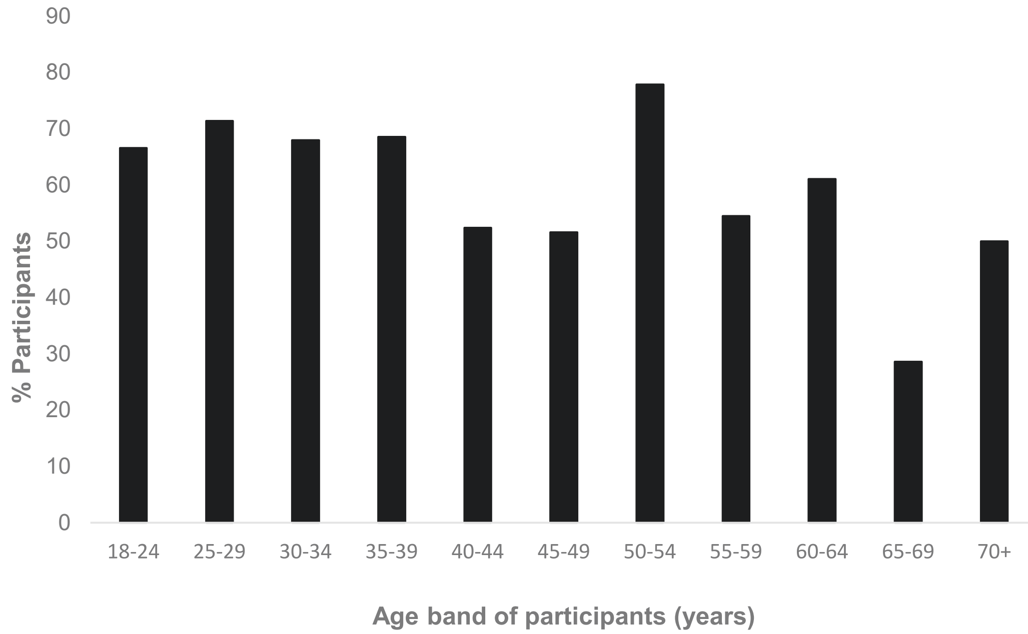

Fig. 3. Percentage of participants by age band (years) with a CVS-Q ≥ 6.

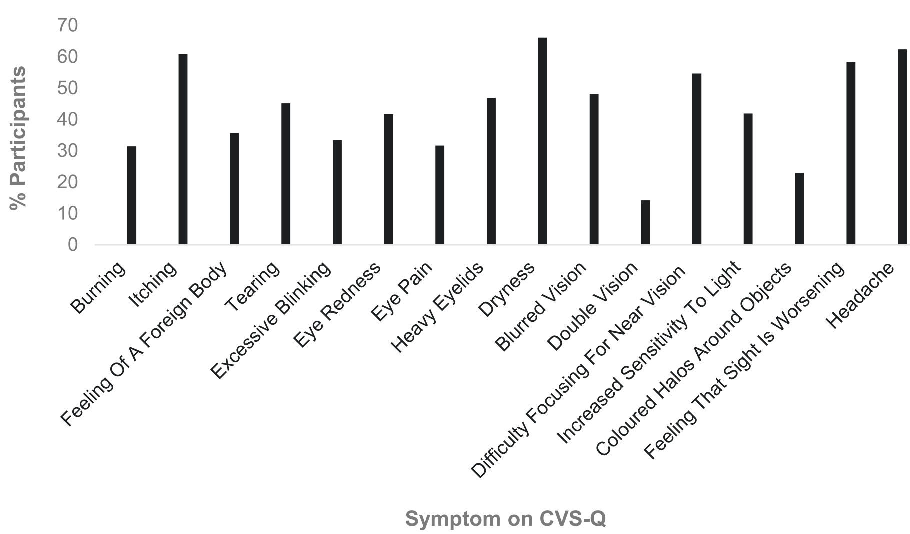

Fig. 4. Percentage of participants selecting each symptom type on CVS-Q (n = 401).

0.1931, $P < 0.00001$). Of the respondents who did not regularly work from home 33.33 % reported having muscular symptoms 'regularly' or 'very frequently' whereas 55.32 % of those who worked a minimum of 16 h per week from home reported having muscular symptoms 'regularly' or 'very frequently'.

3.7. Ocular symptoms

359 (89.5 %) respondents reported ocular symptoms (such as dryness / discomfort / visual problems / strain / headache) with 34.4 % saying they occurred regularly (twice a week or more) or very frequently (most days).

Of those 42 respondents who reported never having symptoms, the highest percentage was in the 45–49 years age group, 23.8 %, with the lowest being in the 25–29, 65–69 and 70 + age groups, all being 2.3 %. Of the respondents who did not regularly work from home, 24.44 % reported having ocular symptoms 'regularly' or 'very frequently' whereas, 39.15 % of those who worked a minimum of 16 h per week from home reported having ocular symptoms 'regularly' or 'very frequently'.

When the participants who reported ocular symptoms (n = 359) were asked to rate how much their symptoms 'bothered' them (on a scale of 1 to 10, 1 being least bothersome and 10 being most bothersome) 4.7 % rated them as being barely noticeable ('bother' score of 1), 42.6 % rated them as being minor ('bother' score of 2 or 3), 44.6 % rated them as being frequent / annoying but not problematic or affecting work ('bother' score of 4, 5 or 6), while 8.1 % said they were severe enough to affect their work ('bother' score of 7, 8, 9, or 10). Fig. 6 below shows a breakdown of the 'bother score' results reported by percentage of participants. Of this symptomatic group, 69 % had a DEQ-5 > 6 and 68.5 % had a CVS-Q ≥ 6. The median of the 'bother score' was 3 (IQR 2–4). When responses between 'bother score' and DEQ-5 are analysed the results are highly positively correlated with Spearman's rank-order correlation coefficient $r_s = 0.63$, $r_s^2 = 0.3969$, $P < 0.00001$ in females and $r_s = 0.71$, $r_s^2 = 0.5041$, $P < 0.00001$ in males. Similarly, when responses between 'bother score' and CVS-Q are analysed the results are

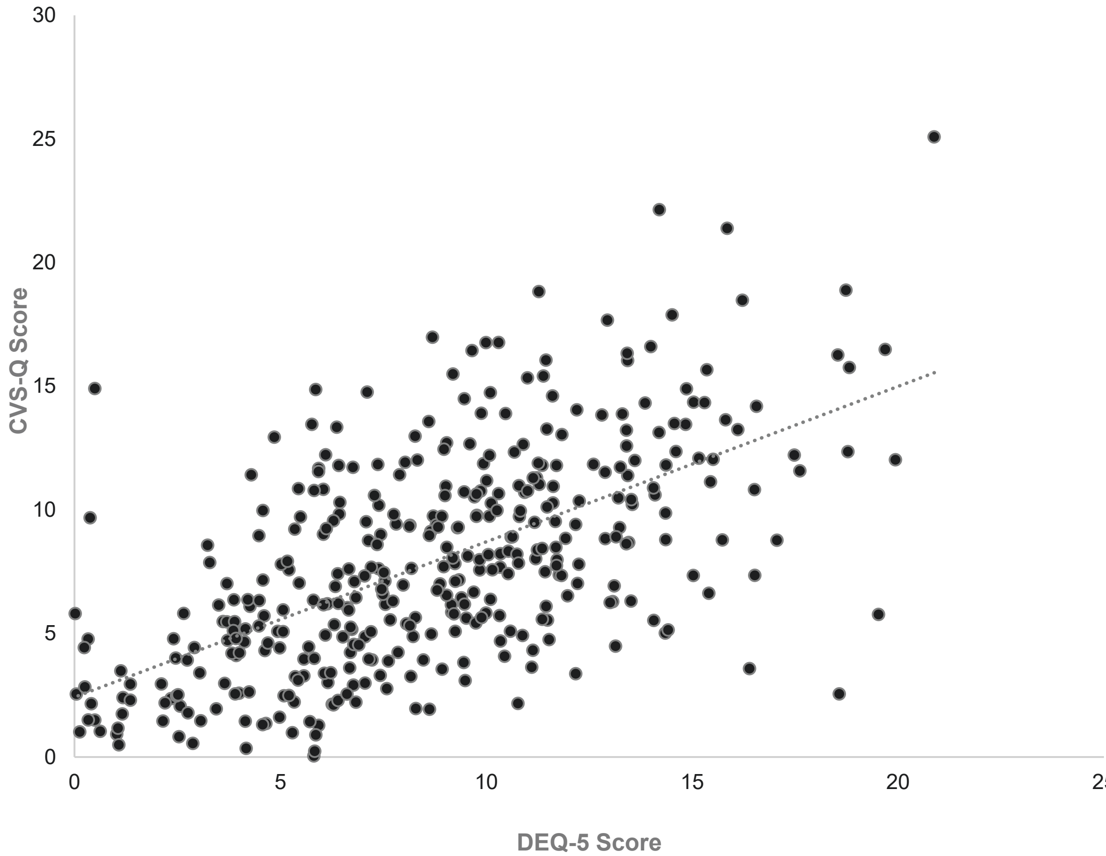

Fig. 5. Correlation between participants DEQ-5 and CVS-Q scores, high positive correlation is shown with Spearman's correlation $r_s = 0.60$, $r_s^2 = 0.36$, $P < 0.00001$. Data have been jittered to improve visibility of overlapping data points.

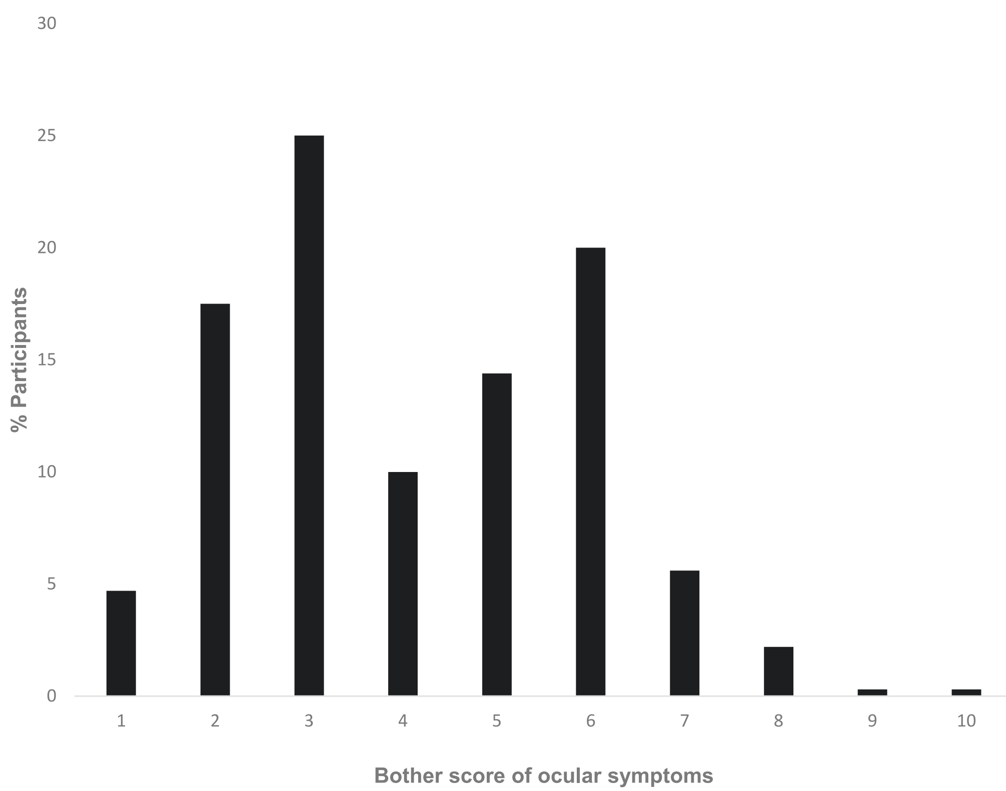

Fig. 6. Scale of 1 to 10 on how bothersome symptoms were when reported by participants (%) n = 359.

highly positively correlated with Spearman's rank-order correlation coefficient $r_s = 0.51$, $r_s^2 = 0.2601$, $P < 0.00001$ in females and $r_s = 0.69$, $r_s^2 = 0.4761$, $P < 0.00001$ in males. When responses between 'bother score' and muscular symptoms are analysed the results are positively correlated with Spearman's rank-order correlation coefficient $r_s = 0.41$, $r_s^2 = 0.1681$, $P < 0.00001$ in females and $r_s = 0.43$, $r_s^2 = 0.1849$, $P < 0.00001$ in males, Fig. 7 shows a scatter plot of 'bother score' and CVS-Q.

3.8. Methods used to relieve symptoms

Of the respondents 7.2 % had not tried anything to relieve their symptoms when using digital devices. Taking regular breaks from the device was the most selected method to reduce symptoms (62.3 % participants), followed by looking away from the screen frequently (49.4 %) and then by adjusting room lighting / window coverings (40.9 %). Some 30.2 % used lubricating drops and 37.7 % used their regular spectacles while 11 % mentioned using specialised 'computer spectacles'. Adjusting the screen settings, such as brightness / colour was mentioned by 34.7 % of the participants, and 13.2 % adjusted their room environment, such as temperature / humidity to help relieve their symptoms. Taking pain medication was mentioned by 15.7 % as being necessary to help cope with their symptoms.

3.9. Self-diagnosed digital eye strain

Two hundred and forty-eight or 61.8 % of respondents selected 'yes' when asked if they considered themselves to be affected by DES, with 38.2 % selecting 'no'. Comparing 'self-diagnosed' DES to the results obtained using the CVS-Q showed agreement in 75 % of participants, agreement between 'self-diagnosed' DES and having dry eye (using the DEQ-5) was found in 71.1 %. Females were more likely to diagnose themselves with DES than males, 65.5 % as opposed to 55 %. The age-bands 50–54 years and 35–39 years self-diagnosed DES the most, 69.1 % and 65.7 % respectively, the 65–69 age band was the least likely to self-diagnose DES (42.8 %). Of the 248 participants who said they thought they were suffering from DES, 81.8 % had earlier indicated that their usage of digital devices had increased since the onset of the COVID-19 pandemic. Additionally, 26.9 % had indicated that they worked from home for between 16 and 30 h per week and 34.1 % indicated they worked from home for more than 30 h per week. When CVS-Q results for values ≥ 6 are compared to 'self-diagnosed' DES, the results are positively correlated with Spearman's rank-order correlation coefficient $r_s = 0.46$, $r_s^2 = 0.2116$, $P < 0.00001$.

3.10. Eyecare

One hundred and eighty-four or 45.9 % of respondents reported having had an eye examination less than 1 year ago, 23.7 % had one between 1 and 2 years ago, 15.7 % had one between 2 and 3 years ago and 6.2 % had one between 3 and 4 years ago. Of those who 'self-diagnosed' having DES, 70 % had an eye examination in the last 2 years. Three hundred and four participants or 75.8 % said they would expect their optometrist to provide advice on managing DES during a routine eye examination with 11.2 % saying they would not. The remaining participants, 13 %, did not know or were not sure. Regarding what type of visual correction used (if any) while operating their digital device, 44.6 % used single vision spectacles, 23.4 % used multifocal spectacles and 3.7 % used 'ready made reading' spectacles. Contact lenses were used by 6.2 % and a further 6.2 % of participants alternated between contact lenses and spectacles. Specialised 'computer' spectacles were used by 11 % of the respondents. No correction was used by 27.2 % of respondents.

Of those who 'self-diagnosed' DES, 44.3 % used single vision spectacles, 26.6 % used multifocal spectacles and 4.4 % used 'ready-made reading' spectacles. Of those wearing contact lenses, 56 % 'self-reported' DES, while 60.5 % of those using no visual correction 'self-reported' DES.

4. Discussion

This cross-sectional survey of digital eye strain (DES) in computer / digital device users in Ireland and the UK and their associated symptoms

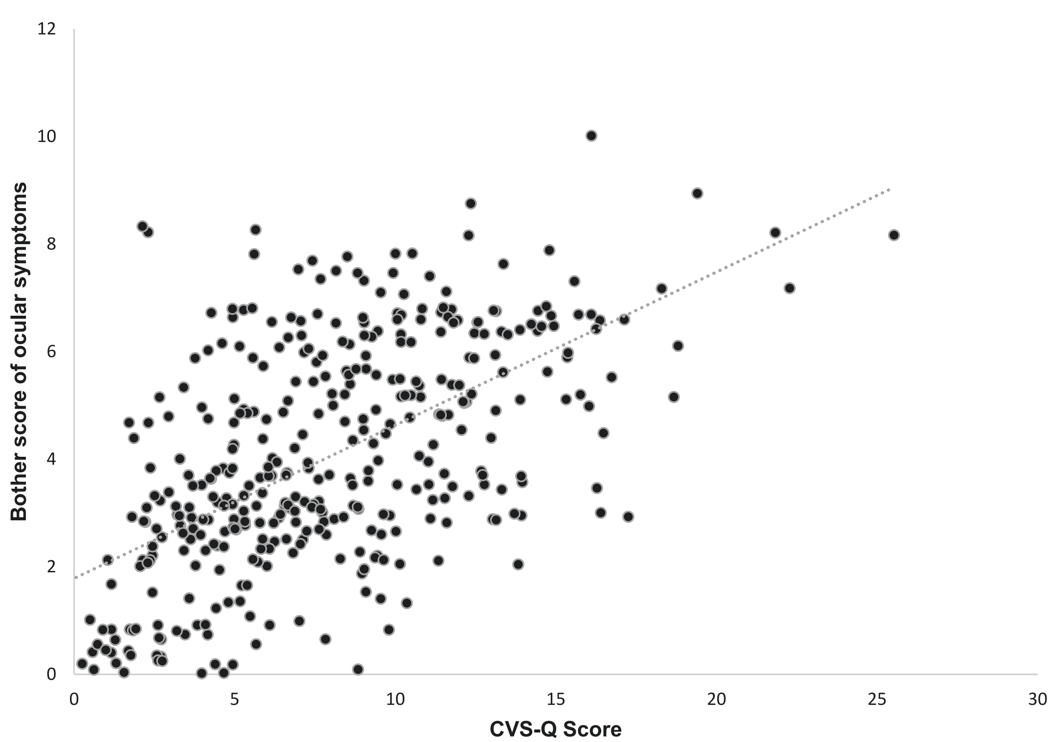

Fig. 7. Scatter plot of bother score of ocular symptoms and CVS-Q score of participants (n = 401) showing positive correlation and trendline. Data have been jittered to improve visibility of overlapping data points.

was the first of its kind and included respondents with a broad range of device usage, various DES signs and symptoms and eye care history. It appears to be, at the time of writing, the first published data on the occurrence of DES (which was already known to be high even before the pandemic) in Ireland and the UK. It examined the impact of those affected by DES and the link between DES and dry eye.

Of the 401 valid respondents, 54.5 % were aged between 40 and 59 years, 33.9 % were aged between 18 and 39 years and the remainder, 11.7 % were aged over 60 years. This represents a good variation of age and allowed the prevalence of DES to be assessed and compared across these different age cohorts. Analysis showed that there was no significant correlation between age and DES (as determined by the CVS-Q) or between age and dry eye symptoms (as determined by the DEQ-5). Other studies have shown a significant link between age and DES and dry eye and DES, such as Uchino *et al.* (2013) [30] and others have not, such as Portello *et al.* (2012) [1]. The former study was carried out in Osaka (Japan) and the latter in New York (USA). The participants of the Portello *et al.* (2012) [1] study were 50.3 % white and 11.7 % Asian whereas the ethnic breakdown for Uchino *et al.* (2013) [30] was not disclosed however the participants were described as 'Japanese office workers' so it could be presumed that they were predominantly Asian. In this study the participants were 90 % white and 5.75 % Asian, this could account for a similar finding with respect to age and DES and dry eye symptoms and DES as found by Portello *et al.* (2012) [1] and could suggest that device users who are white are less likely to experience DES than other ethnic groups. Given that Asian ethnicity is a predisposing risk factor for dry eyes [25] and the established link between dry eye and DES [26–28], this finding is therefore not a surprising one (however it should be noted that due to the relatively small percentage of non-white participants in this study a definitive conclusion cannot be made on the link between ethnicity and DES based on this population alone).

A negative correlation between age and hours per day of device use was shown in this study and a positive correlation was shown between hours per day of device use and DES (as measured by the CVS-Q). This would agree with findings in other studies [1,29–31] were DES was shown to be associated with long hours of device use. Significantly these other studies were conducted in various parts of the world with a variety of ethnic groups and as such this would suggest that ethnicity may not be a factor when considering hours of use and DES.

The gender breakdown of the respondents in this study was 65.6 % female and 34.9 % male. Participation rates of females in online surveys has been shown to be higher than males [32] so this is not a surprising outcome. Given that the female percentage in the workplace in the UK is 47.6 % and 45.8 % in Ireland [33] it would appear that the female responses are in excess of that in the general workplace population [33]. Many studies in DES (both recent and older) have found higher rates in females and this study would agree with this finding [1,5,34–36].

Based on a CVS-Q score ≥ 6 the occurrence of DES in this UK and Ireland population was high, 62.6 %, with females having a significantly higher median score than males. Other studies, such as that by Portello *et al.* (2012) [1], have shown a lesser level of DES of around 50 %, where as other research has suggested it may be even higher than that found in this study, at between 64 % and 90 % [37,38]. Another survey of computer users showed that 'visual complaints' were reported by 75 % of computer users who work 6–9 h per day in front of their screens [39]. A further survey of 419 computer users in India reported that 46.3 % of the users experienced two or more symptoms of DES either during or after computer work [40]. Additionally, DES was also reported in over 50 % of call centre computer workers in Sao Paulo, Brazil [41]. Research since the COVID-19 pandemic has shown varying prevalence's of DES, such as 82.41 % by Zayed *et al.* (2021) [31] and 62.4 % by Ahuja *et al.* (2021) [44]. These studies have used various criteria for the diagnoses of DES which could explain their differing results. It would be beneficial to the research in this area if all studies used a recognised and validated instrument for the diagnoses of DES, such as the validated CVS-Q, to make their results comparable. Working from home also appeared to be linked to higher CVS-Q scores with 64.6 % of those working from home having a score ≥ 6, this is not a surprising finding as it may not be possible to set up an ergonomically designed workstation at home as easily as in an office environment.

Another key finding of the study is that most (75.8 %) of the respondents said they would expect their optometrist to provide advice on managing DES, this combined with the increasing use of digital devices, may result in more users attending their optometrist looking for help in dealing with this condition. This finding, combined with the research by Moore *et al.* (2021) [9] that 88.9 % of optometrists agree that DES is an important concern for them in practice and that 91.4 % say they feel confident in dealing with it, shows that the optometry profession is in a good position to deal with and manage this condition in their patients. Moore *et al.* (2021) [9] further found that 91.9 % of optometrists agreed that DES can cause frequent and persistent symptoms for sufferers, therefore the device user should be confident that their concerns about DES will be taken seriously and dealt with correctly.

Analysis of the type of device(s) used by the participants found that most used a smart phone, 95.5 %, followed by laptop, 80.8 % and desktop computer, 54.1 %. This finding is to be expected given that almost every adult in the UK and Ireland now uses / owns a mobile phone [42,43]. The greater use of laptops than desktops could be explained by the increase in working from home that has occurred since the COVID-19 pandemic, with 77.6 % of the participants indicating that they worked from home for at least part of their working week.

The mean number of hours that devices were used for was 9.7 h which is similar as that found in other studies [5,31,44]. The range of hours used was from 1 to 24, with 81 participants saying they used their devices for $\geq$ 12 h a day and 31 saying they used their devices for $\geq$ 16 h a day. This seemingly very high number of hours that some participants reported using their devices could perhaps be explained by the use of multiple devices simultaneously, for example using a laptop and a desktop or tablet while sitting at their desk and also having their smartphone open (Sheppard and Wolffsohn (2018) [3] reported 87 % of individuals aged 20–29 years use two or more digital devices simultaneously for multiple tasks so this is not an unexpected finding). It would appear also that some device users considered having their device open and available for use was the same as actually using their device, which could mean that hours of use reported by users in other circumstances may not reflect actual device usage at all. To record this more precisely, an objective measurement of device use would be a more accurate way of determining actual screen use. Such objective measurements have been used in other studies, for example Ostrin *et al.* (2018) [59] used a smart watch type device to measure daylight exposure in children and Apple (Apple, Cupertino, CA, USA) iPhones and iPad devices also permit time on their devices to be recorded and a user report to be generated. In their study on the effectiveness of the 20/20/20 rule, Talens-Estarelles *et al.* (2022) [49] found a similar finding where participants in their study reported using devices for an average of 7 h per day, whereas specially installed software (which monitored their use) recorded an average of just 4 h per day which would suggest that individuals may tend to overestimate their duration of device use. If device usage software, such as that, was used it may be possible to get a more accurate assessment of their actual device usage.

Of the 401 participants in this study who completed the DEQ-5 questionnaire, 61.8 % had a score of > 6; of the female participants 70.7 % had a score > 6 and 47.14 % of males had a score > 6. This finding is consistent with other studies which show that females are more likely to have dry eye symptoms than males [5,31,36,45]. Some recent studies [20] have considered a score ≥ 6 in the DEQ-5 to be indicative of dry eye syndrome, if this metric is used in this study, then the percentage of participants would increase to 72.3 %. This indicates that dry eye symptoms amongst device users are pervasive. This is a similar finding to that in other studies where a clear link between DES and dry eye has been established [5]. However, the study showed that only 30.2 % of participants used ocular lubricants to relieve their symptoms, while this is higher than the 20.5 % figure found by Portello *et al.* (2012) [1] it is still relatively low. As such the use of correct ocular lubricants needs to be encouraged in symptomatic device users. The optometry profession, given the findings in this study and by Moore *et al.* (2021) [9] that the use of lubricants for the relief of DES was considered to be important by 94.6 % of optometrists, should be in a good position to achieve this.

The results of the DEQ-5 and the CVS-Q are highly correlated (Spearman's correlation $r_s = 0.60$, $r_s^2 = 0.36$, $P < .00001$) indicating a definite link between dry eye symptoms and DES. In addition, there is also good correlation between the findings of the CVS-Q and for the 'self-diagnosing' of DES (Spearman's correlation $r_s = 0.46$, $r_s^2 = 0.2116$, $P < 0.00001$). This would indicate that device users are reasonably accurate in self-diagnosing DES. Therefore, if a device user indicates that they think have DES there is a good possibility that they do indeed have it.

Musculoskeletal symptoms were reported by 94.3 % of device users (which is a similar finding to that Basu *et al.* [60] in their 2014 study in India) with 19.2 % reporting them to occur most days. Participants reporting musculoskeletal symptoms were also correlated with positive DEQ-5 and CVS-Q scores. When considering DES these symptoms in device users could be overlooked (as more attention is paid to ocular symptoms), but this finding would appear to confirm that musculoskeletal symptoms are a very common occurrence that deserves attention. Symptoms were more likely in those working from home which could be due to their workstation being less ergonomic than that in a typical office environment.

Ocular symptoms were reported by 89.5 % of respondents, with 34.4 % saying they occurred regularly or very frequently, however when asked to rate how much their symptoms bothered them, only 8.1 % said they were severe enough to affect their work. Working from home was again shown to have a higher likelihood of symptoms than those who did not work regularly from home. Both CVS-Q results and DEQ-5 results were highly positively correlated with the participants bother score as were muscular symptoms, showing that while CVS-Q and DEQ-5 are designed to measure ocular symptoms of DES they are also a good predictor of non-ocular symptoms.

The finding that only 8.1 % of participants considered their symptoms to be significant enough to affect their work is novel and important as it indicates that while DES is prevalent in this cohort of device users, in the vast majority of those who 'suffer' from it, it appears to have no significant effect on them. This finding is different to that reported in other studies [1,46], where device user's symptoms were reported to have a more significant effect on their performance. While this type of questioning has not been validated or shown to be repeatable, if this finding were to be repeated in subsequent studies, it could indicate that the significance of DES on the typical device user has perhaps been over estimated. One possible explanation for this finding could be that the participants in this study were predominantly based in a university and therefore may have had better advice about workstation setup and eyecare than that given to other types of office workers.

Taking regular breaks was the means used by most respondents to reduce their DES symptoms (62.3 %). This has been shown to significantly reduce DES symptoms in several studies [47,48] and device users should be advised of its benefits especially when using devices for many hours. Looking away from the screen was another method used to reduce symptoms by many participants (49.4 %); this latter strategy combined with taking breaks was found by Reddy *et al.* (2013) [58] to further reduce symptoms. Many optometrists advise their patients to use the 20/20/20 strategy (where after 20 min of device use, the user looks at objects 20 feet away for 20 s) which combines both taking breaks and looking into the distance and this has been found to be effective in reducing DES and dry eye symptoms when using digital devices [49]. Moore *et al.* (2021) [9] reported that 98.2 % of optometrists considered taking breaks and looking into the distance to be important in reducing symptoms of DES in device users and as such those attending their optometrist for advice on dealing with DES should be reassured that they will be informed of the importance of this strategy.

Many respondents also adjusted their screen settings, workplace setup and environment to reduce the occurrence of DES symptoms. Again, this has been shown to reduce DES [50–53] and device users should be educated to know how this can be done to reduce DES. Moore *et al.* (2021) [9] showed that 97 % of optometrists considered giving advice on the office environment and workstation setup to be important and should be able to advise their patients on how to do this. However, given the high numbers of device users who reported working regularly from home, this could be difficult as many users may not be able to adjust their 'home-office' setup to that which is optimal or recommended for the reduction of DES. As such employers should consider advising their employees who regularly work from home how to best to set up their workspace to reduce the occurrence of DES. The College of Optometrists (UK) and the Association of Optometrists Ireland could produce and circulate a document with advice on how this could be done thereby further enhancing the role of the profession in managing DES with the public.

Three hundred and four or 75.8 % of participants would expect their optometrist to provide advice to them during their eye examination about DES which is a significant finding for the optometry profession as it shows that patients / clients expect optometrists to be knowledgeable in this area and would value their opinion in dealing with an ever-increasing problem. Moore *et al.* (2021) [9] showed optometrists appreciate the difficulty their patients can have with DES and are ready to provide advice and help to reduce its symptoms. Of the participants who considered themselves to be suffering from DES, 70 % reported having had an eye examination in the last two years which could indicate that this cohort are aware of the help they can get from their optometrist with respect to DES and as such attend for regular eye examinations.

Almost half of respondents, 44.6 %, used single vision spectacles when using their device(s) with 23.4 % using multifocal spectacles. No spectacles were used by 27.2 % of respondents, this latter figure could be accounted for by the fact that 33.9 % of the respondents were under the age of 40 and as such would not be at an age where presbyopia is evident [54,55]. Self-diagnosed DES was high in those who used ready-made reading spectacles, 73.3 % (albeit from a small sample size) which could be accounted for by the lack of astigmatic correction in this type of correction given that astigmatism has been shown in previous studies to cause significant visual discomfort and reduced productivity in device users [56,57]. Only 11 % of respondents used specialised 'computer' spectacles to reduce their DES symptoms and none mentioned using 'blue light' filtering spectacle lenses. Given the publicity (notably on social media platforms) about the use of these 'blue light' filtering spectacle lenses (especially since / during the COVID-19 pandemic) this is a surprising finding. Moore *et al.* (2021) [9] found that the use of specialist spectacle lenses in DES management was an area where optometrists lacked confidence (11.3 % reporting they did not know how important it was to advise on this type of correction and only 34.2 % felt they were extremely or very important in managing DES). With a range of specialist lens types now available for both pre-presbyopic and presbyopic digital device users this could represent an area where further education would be of value to the optometry profession which in turn could provide device users with advice on whether these specialist lens types are suitable for them.

As with all research this study has some shortcomings. While the minimum number of valid respondents required was exceeded, the study could have benefited from a more equal gender and age balance (given the suspected effect of gender and age on the prevalence of DES). Respondents were predominantly office workers and, as such, not fully representative of the entire UK or Irish workforce. Therefore, it is possible that different results may have been obtained if workers in other working environments who also use digital devices on a daily basis, such as factory floors, retail etc. were questioned. It was also difficult to quantify the accurate usage of devices with many users apparently equating device usage with the availability of device use (as stated earlier an objective measurement of device use would have been of benefit in this study and should be considered for future work in this area). As with all studies, those who have an interest in DES, or who believe they have or suffer from DES, may be more motivated to complete the study than those that do not. Questions could also have been asked about the number of years the participants have been using digital devices as part of their work and some details could have been requested about their workstation setup, such as viewing distance, screen height, screen position with respect to windows etc. and while this was considered, the research team felt it would have presented the participant with a much longer and cumbersome survey and that may have had negative consequences with some abandoning the survey before it was fully complete.

Further work in the area of DES in an older population would be of benefit, as in this study only 11.7 % of participants were aged over 60, so specific problems relating to this age cohort and DES may not have been detected.

5. Conclusion

This study provides a valuable insight into DES in digital device users in Ireland and the UK and is the first of its kind to be completed. It shows, that while the level of DES is high in device users, at 62.6 %, the actual effect or consequences of it on them does not appear to be significant. For the first time it shows a clear correlation between the DEQ-5 and CVS-Q questionnaires. It shows that device users expect their optometrist to advise them on DES and to be knowledgeable of the condition and as such these findings should encourage the profession to educate it's members further in this area.

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