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Impact of the COVID-19 pandemic on eye strain and dry eye symptoms

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ABSTRACT

Purpose: Among adult individuals with dry eye, assess the self-reported impact of the COVID-19 pandemic on (1) dry eye-related visual function, (2) reading efficiency, and (3) dry eye treatments used.
Methods: In June–July 2020, we conducted an online survey of adults with dry eye who spent at least somewhat more time at home during the pandemic than before. Consistent with TFOS DEWS II guidelines, we categorized respondents into mild, moderate, or severe dry eye based on treatment usage.
Results: We included 388 respondents: 97 respondents (25%) with mild, 80 (21%) with moderate, and 211 (54%) with severe dry eye. In all three groups, screen/reading time generally doubled during the pandemic. Reduced work-related efficiency was noted by a considerable proportion of respondents (moderate dry eye: 51%, mild: 39%, and severe: 38%). Compared with respondents with mild dry eye, respondents with moderate dry eye were considerably more likely to note worsening symptoms: eye pain (OR = 2.57, 95% CI 1.22–5.41), headache from eye symptoms (OR = 2.34, 95% CI 1.11–4.90), and difficulty concentrating because of eye symptoms (OR = 2.79, 95% CI 1.37–5.66). Respondents with moderate dry eye with Sjögren's syndrome were most likely to note these. Respondents with severe dry eye were more likely than respondents with mild dry eye to report losing access to dry eye-related treatments (OR = 2.62, 95% CI 1.36–5.03).
Conclusions: The COVID-19 pandemic-related eye strain may be impacting symptoms, performance, and ultimately employment, especially for those with moderate dry eye. This may be compounding the already-high dry eye-related societal burden.

Introduction

Dry eye, a common multifactorial ocular surface condition resulting from disturbances to homeostasis of the tear film, can have substantial negative impact on quality of life [1–4] and function [5].

One key functional impairment in dry eye is difficulty with activities requiring sustained gazing, such as reading. Numerous studies have documented dry eye-related reductions in reading speed [6–8]. The impact of dry eye on reading speed is directly proportional to the severity of signs and symptoms [9] and to the duration of prolonged gazing [8]. Reduction in reading speed is thought to be related to blurring of the image on the retina due to an unstable tear film over the irregular corneal epithelium in the setting of dryness and/or inflammation, which accelerates visual fatigue [7,8]. Fatigue may occur irrespective of whether the prolonged gazing is for work or leisure and whether it is directed at electronic devices or printed material. Corneal epithelial dryness and inflammation also contribute to visual discomfort, which in turn impacts visual fatigue and lowers reading speed [7].

During the ongoing coronavirus disease 2019 (COVID-19) pandemic, large segments of populations, including patients with dry eye, are spending increased time at home.[10] Reductions in outdoor activities, social engagements, and travel and commuting time, and increases in time spent indoors have led to increased 'screen time' (time viewing screens of computers, hand-held devices, etc.) and/or increased time spent reading than before the pandemic [11,12]. Other aspects of the indoor environment, such as low humidity and draft air, may also be

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related to worsening dry eye [10,13].

We hypothesized that the pandemic-related stay-at-home measures and consequent increases in screen time and eye strain have negatively impacted overall visual function, ocular discomfort, and eye fatigue, and that these impacts are greater in individuals with moderate or severe dry eye. Herein, we describe a survey conducted during the early months of the COVID-19 pandemic to test our hypotheses.

Purpose

To assess the self-reported impact of the COVID-19 pandemic on [1] dry eye-related visual function [2], reading efficiency, and [3] use of dry eye-related treatments in adults with dry eye.

Methods

This was a cross-sectional study. The Brown University Institutional Review Board (IRB) approved its conduct (IRB #2005002721).

Development of survey

We chose questions for the survey based on our (I.J.S., R.P., M.M., E. K.A.) prior published surveys [14–17]. We then adapted the questions to reflect the visual difficulties experienced by patients with dry eye arising from increased eye strain during the ongoing COVID-19 pandemic. To facilitate comprehension in lay language, R.P. (a longtime patient advocate with dry eye) revised the survey (Appendix 1). Once final, the instrument comprised 28 questions organized into seven sections: (A) assessment of respondent eligibility, (B) employment status (before and during the pandemic), (C) presence and severity of dry eye, Sjögren's syndrome ("Sjögren's") status, (D) screen time and reading time (before and during the pandemic), (E) changes in dry eye symptoms and visual function, (F) changes in treatments for dry eye, and (G) demographic information. Questions in sections D, E, and F used Likert-type scaling. We implemented the survey using Qualtrics® (Provo, Utah).

Target population

Our target population was adults (≥18 years old during the survey) with self-reported dry eye who had been spending at least somewhat more time at home during the COVID-19 pandemic than before the pandemic. We left the interpretation of 'somewhat more time' up to respondents. We informed them to consider 'during the pandemic' as the week before completing the survey and 'before the pandemic' as the week before stay-at-home restrictions were in place at *their* location or the week before March 20, 2020, whichever was more applicable.

Dissemination of survey

We partnered with the Dry Eye Foundation (Poulsbo, Washington, USA) and the Sjögren's Foundation (Reston, Virginia, USA). Both organizations have an international membership. To disseminate the survey, we:

- Sent an invitation email with a brief description and the survey link to subscribers of the Dry Eye Foundation mailing list;
- Posted the survey invitation on social media platforms (Facebook® and Twitter®) of the Dry Eye Foundation and the Sjögren's Foundation; and
- Shared the survey invitation with our personal social media platforms.

We promoted this anonymous and voluntary survey three times: on June 30, 2020 and through two reminders 1 week and 2 weeks later. The survey was open until July 21, 2020.

Exposure (dry eye severity) classification

In accordance with the Tear Film and Ocular Surface Society (TFOS) Dry Eye Workshop II (DEWS II) guidelines [18], we categorized respondents into mild, moderate, or severe dry eye based on treatment usage. Briefly, we classified respondents as having *severe dry eye* if they reported using any of the following specialized treatments for dry eye: dry eye goggles/glasses, special contact lenses, in-office treatments, or TrueTear®. Respondents who did not report using specialized treatments but reported using prescription eye drops, gels, or ointments were classified as having *moderate* dry eye. Respondents who did not report using any of the above treatments but reported using over-the-counter lubricant drops, gels, or ointments or warm compresses were classified as having *mild* dry eye. We classified respondents as having mild dry eye even if they did not report any treatment but reported being diagnosed with dry eye by a healthcare professional and experiencing at least one of the 18 symptoms listed in the survey.

Outcome classification

To estimate changes in eye strain-related symptoms and visual function, we considered a symptom/visual function to have worsened if the respondent rated it as "somewhat worse" or "much worse" during the pandemic (Purpose 1). To estimate changes in reading efficiency, we considered a particular efficiency measure to have worsened if the respondent rated it as "somewhat worse" or "much worse" during the pandemic (Purpose 2). To estimate changes in use of dry eye-related treatments, we considered use of a particular treatment to have increased if the respondent reported that they used it "somewhat more" or "much more" during the pandemic (Purpose 3).

Statistical analysis

We considered respondents with mild dry eye as the reference group. To compare outcomes between this group and the two "exposed" groups (moderate dry eye and severe dry eye), we calculated adjusted odds ratios (ORs) with 95% confidence intervals (CIs) using multivariable logistic regression analyses. All ORs reported herein are adjusted for age, sex, race, and employment status. We used STATA® Version 16 for all statistical analyses.

Results

Respondents

In total, 1047 individuals clicked through to the survey information page and 710 completed it (completion rate = 68%). We excluded 322 of 710 responses (45%) that did not meet eligibility criteria: 292 respondents reported spending no more time at home during the pandemic compared with before; 15 respondents did not report dry eye diagnosis by a healthcare professional, dry eye symptoms, or dry eye-related treatments; 11 respondents did not report dry eye diagnosis by a healthcare professional or dry eye-related treatments; and four respondents reported being younger than 18 years old.

This study includes 388 adult respondents who completed the survey: 97 individuals (25%) with mild dry eye, 80 (21%) with moderate dry eye, and 211 (54%) with severe dry eye (Table 1). Among all 388 respondents, the median age was 56 years (interquartile range 44–64), and 62% were more than 50 years old. Age distributions were similar across dry eye severity categories. Most respondents in the entire group were women (86%), White (89%), and not Hispanic (89%). More than 90% of all respondents resided in the U.S., U.K., or Canada during the survey.

Table 1
Demographic characteristics and professional status of all survey participants.

Characteristic	MILD dry eye (N = 97) n (%)	MODERATE dry eye (N = 80) n (%)	SEVERE dry eye (N = 211) n.(%)	ALL Respondents (N = 388) n (%)
Age (years) n (%)				
18 to 30	4 (4)	2 (3)	15 (7)	21 (5)
31 to 40	16 (17)	8 (10)	28 (13)	52 (13)
41 to 50	17 (18)	10 (13)	31 (15)	58 (15)
51 to 60	20 (21)	27 (34)	48 (23)	95 (25)
61 to 70	29 (30)	19 (29)	51 (24)	99 (26)
71 to 80	5 (5)	7 (9)	21 (10)	33 (9)
81 or older	0 (0)	1 (1)	5 (2)	6 (2)
Declined to answer	6 (6)	6 (8)	12 (6)	24 (6)
Sex n (%)				
Female	88 (91)	71 (89)	175 (83)	334 (86)
Male	9 (9)	9 (11)	34 (16)	52 (13)
Declined to answer	0 (0)	0 (0)	2 (1)	2 (1)
Race[a] n (%)				
White	90 (93)	74 (93)	181 (86)	345 (89)
Black or African American	3 (3)	1 (1)	4 (2)	8 (2)
Asian	3 (3)	1 (1)	11 (5)	15 (4)
American Indian or Alaskan Native	0 (0)	0 (0)	5 (2)	5 (1)
Native Hawaiian or Other Pacific Islander	0 (0)	1 (1)	0 (0)	1 (0)
Not listed above	0 (0)	1 (1)	8 (4)	9 (2)
Declined to answer	1 (1)	3 (4)	6 (3)	10 (3)
Ethnicity n (%)				
Hispanic or Latino	3 (3)	4 (5)	15 (7)	22 (6)
Not Hispanic or Latino	90 (93)	71 (89)	185 (88)	346 (89)
Declined to answer	4 (4)	5 (6)	11 (5)	20 (5)
Country of residence n (%)				
United States	79 (81)	63 (79)	172 (82)	314 (81)
United Kingdom	5 (5)	9 (11)	10 (5)	24 (6)
Canada	7 (7)	3 (4)	12 (6)	22 (6)
Australia	3 (3)	0 (0)	2 (1)	8 (2)
India	0 (0)	1 (1)	1 (1)	6 (2)
Mexico	1 (1)	1 (1)	3 (1)	5 (1)
Not listed above	2 (2)	3 (4)	11 (5)	16 (4)
Professional status BEFORE PANDEMIC[a] n (%)				
Employed (including self-employment), full time	44 (45)	31 (39)	125 (59)	200 (52)
Employed (including self-employment), part time	17 (18)	15 (19)	23 (11)	55 (14)
Student, full time	1 (1)	2 (3)	5 (2)	8 (2)
Student, part time	1 (1)	2 (3)	3 (1)	6 (2)
Homemaker or not employed	12 (12)	18 (23)	32 (15)	62 (16)
Retired	25 (26)	22 (28)	48 (23)	95 (25)
Professional status in LAST TWO WEEKS (DURING PANDEMIC)[a] n (%)				
Employed (including self-employment), full time	40 (41)	26 (33)	119 (56)	185 (48)
Employed (including self-employment), part time	15 (16)	16 (20)	23 (11)	54 (14)
Student, full time	1 (1)	1 (1)	4 (2)	6 (2)
Student, part time	1 (2)	1 (1)	2 (1)	4 (1)
Homemaker or not employed	17 (18)	23 (29)	38 (18)	78 (20)
Retired	25 (26)	21 (26)	45 (21)	91 (24)
CHANGE in professional status during versus before pandemic n (%)				
No change	87 (90)	70 (88)	202 (96)	359 (92)
Some change	10 (10)	10 (12)	9 (4)	29 (8)
Because of the pandemic?	80%	90%	100%	93%
Full-time (employment or student) → Part-time (employment or student)	3 (3)	3 (4)	2 (1)	8 (2)
Because of the pandemic?	100%	67%	100%	88%
Full-time (employment or student) → Homemaker/non-employed	2 (2)	3 (4)	3 (1)	8 (2)
Because of the pandemic?	100%	100%	100%	100%
Full-time (employment or student) → Retired	0 (0)	0 (0)	0 (0)	0 (0)
Because of the pandemic?	N/A	*N/A*	*N/A*	*N/A*
Part-time (employment or student) → Full-time (employment or student)	1 (1)	0 (0)	0 (0)	1 (0)
Because of the pandemic?	0%	*N/A*	*N/A*	0%
Part-time (employment or student) → Homemaker/non-employed	4 (4)	4 (5)	4 (2)	12 (3)
Because of the pandemic?	100%	100%	100%	100%
Part-time (employment or student) → Retired	0 (0)	0 (0)	0 (0)	0 (0)
Because of the pandemic?	*N/A*	*N/A*	*N/A*	*N/A*
Change in efficiency during the pandemic (among respondents with no change in professional status before vs. during the pandemic) n (%)	n = 87	n = 70	n = 202	n = 359
Decrease in efficiency	34 (39)	36 (51)	77 (38)	147 (41)
No change	25 (29)	17 (24)	53 (26)	95 (27)
Increase in efficiency	21 (24)	17 (24)	63 (31)	101 (28)
Not sure	7 (8)	0 (0)	9 (5)	16 (5)

[a] Respondents could select more than one response.

Professional status

Respondents with moderate dry eye were employed to a lesser extent than respondents with mild or severe dry eye (Table 1). Before the pandemic, less than half (42%) of the respondents with moderate dry, and 46% of respondents with mild dry eye, were in full-time status (i.e., full-time employees or full-time students). In contrast, 61% of respondents with severe dry eye were in full-time status. Across groups, approximately a quarter of respondents were retired. A similar pattern was observed during the pandemic. Although only 8% of respondents experienced a change in professional status during the pandemic (the survey was conducted in the first 3–4 months of the pandemic), *almost all* respondents who experienced a change (27/29; 93%) attributed it to the pandemic. The changes were mostly from part-time status to homemaker/not employed or from full-time to part-time status.

Almost half (41%) of the 359 respondents whose professional status remained the same during the pandemic noted a decrease in efficiency related to their work. This percentage was considerably higher in respondents with moderate dry eye (51%) than mild (39%) or severe dry eye (38%).

Dry eye severity

Most respondents (81%), whether mild, moderate, or severe dry eye, had been living with it for 3+ years (**Appendix 2**). Thirty-two percent of respondents with severe dry eye had visited their healthcare professional for dry eye 4+ times in the year preceding the pandemic compared with only 18% of respondents with moderate dry eye and 4% of respondents with mild dry eye. A large proportion (61%) of all 388 respondents had been diagnosed with Sjögren's, including 76% of respondents with mild dry eye, 74% with moderate dry eye, and 49% with severe dry eye.

Screen/reading time

Appendix 3 details the duration of screen/reading before and during the pandemic, stratified by device type. As expected, screen/reading time generally increased in all three groups of respondents, irrespective of dry eye severity. Similar patterns were observed across groups, and so we summarize results for all respondents here. Overall, for most electronic devices, the proportion of respondents who spent 5+ hours per day viewing the device approximately doubled during the pandemic. These included cellphones (11% before vs. 25% during), other handheld devices (5% vs. 13%), laptop computers (18% vs. 34%), televisions (8% vs. 16%), and other electronic devices (2% vs. 4%). However, the proportion of respondents who spent 5+ hours per day viewing desktop computers and reading/writing on paper did not increase. We hypothesize that this was because only few respondents may have had home desktop computers and because some work-related extended-duration activities (e.g., meetings, classes), conducted mostly in person before the pandemic, were being conducted mostly by viewing screens (e.g., laptop computers) during the pandemic.

Changes in eye strain-related symptoms and visual function

Dry eye was associated with worsening eye strain-related symptoms and visual function during the pandemic, and these associations were considerably stronger for respondents with moderate dry eye in the setting of Sjögren's. Compared with respondents with mild dry eye, respondents with moderate dry eye were considerably more likely to note increased eye pain (OR = 2.57, 95% CI 1.22 to 5.41), increased headache because of eye symptoms (OR = 2.34, 95% CI 1.11 to 4.90), and increased difficulty concentrating because of eye symptoms (OR = 2.79, 95% CI 1.37 to 5.66) (Table 2). Respondents with moderate dry eye in the setting of Sjögren's were also more likely to note increased eye pain (OR = 2.47, 95% CI 1.21 to 5.05), increased headache because of

Table 2
Change in eye strain-related symptom and visual function among all survey participants and association with dry eye severity.

Eye strain-related symptom	MILD dry eye (N = 97) n (%)	MODERATE dry eye (N = 80) n (%)	SEVERE dry eye (N = 211) n (%)	ALL Respondents (N = 388) n (%)
Dryness of the eyes				
Not applicable	1 (1)	2 (3)	6 (3)	9 (2)
Much better	0 (0)	1 (1)	8 (4)	9 (2)
Somewhat better	13 (13)	7 (9)	22 (10)	42 (11)
No change	30 (31)	18 (23)	55 (26)	103 (27)
Somewhat worse	36 (37)	31 (39)	66 (31)	133 (34)
Much worse	17 (18)	21 (26)	54 (26)	92 (24)
Adjusted OR (95% CI)	Ref	1.69 (0.87, 3.27)	1.09 (0.65, 1.82)	
Burning of the eyes				
Not applicable	16 (17)	10 (13)	19 (9)	45 (12)
Much better	1 (1)	1 (1)	9 (4)	11 (3)
Somewhat better	9 (9)	6 (8)	12 (6)	27 (7)
No change	29 (30)	20 (25)	57 (27)	106 (27)
Somewhat worse	29 (30)	28 (35)	77 (37)	134 (35)
Much worse	13 (13)	15 (19)	37 (18)	65 (17)
Adjusted OR (95% CI)	Ref	1.49 (0.75, 2.97)	1.36 (0.79, 2.36)	
Itching of the eyes				
Not applicable	17 (18)	13 (16)	30 (14)	60 (16)
Much better	0 (0)	1 (1)	5 (2)	6 (2)
Somewhat better	8 (8)	5 (6)	13 (6)	26 (7)
No change	30 (31)	20 (25)	76 (36)	126 (33)
Somewhat worse	33 (34)	24 (30)	55 (26)	112 (29)
Much worse	9 (9)	17 (21)	32 (15)	58 (15)
Adjusted OR (95% CI)	Ref	1.51 (0.77, 2.98)	0.84 (0.49, 1.45)	
Foreign body sensation				
Not applicable	21 (22)	12 (15)	34 (16)	67 (17)
Much better	1 (1)	0 (0)	5 (2)	6 (2)
Somewhat better	4 (4)	4 (5)	6 (3)	14 (4)
No change	34 (35)	26 (33)	88 (42)	148 (38)
Somewhat worse	29 (30)	24 (30)	43 (20)	96 (25)
Much worse	8 (8)	14 (18)	35 (17)	57 (15)
Adjusted OR (95% CI)	Ref	1.60 (0.81, 3.18)	0.82 (0.47, 1.44)	
Frequent and/or rapid blinking of the eyes				
Not applicable	27 (28)	15 (26)	40 (19)	82 (21)
Much better	0 (0)	0 (0)	2 (1)	2 (1)
Somewhat better	6 (6)	3 (4)	10 (5)	19 (5)
No change	33 (34)	32 (39)	90 (43)	154 (40)
Somewhat worse	26 (27)	21 (26)	35 (17)	82 (21)
Much worse	5 (5)	10 (13)	34 (16)	49 (13)
Adjusted OR (95% CI)	Ref	1.30 (0.65, 2.62)	0.82 (0.46, 1.46)	N/A
Sensitivity to light				
Not applicable	11 (11)	9 (11)	28 (13)	48 (12)
Much better	0 (0)	0 (0)	3 (1)	3 (1)
Somewhat better	7 (7)	6 (8)	10 (5)	23 (6)
No change	39 (40)	28 (35)	83 (39)	150 (39)
Somewhat worse	26 (27)	20 (25)	50 (24)	96 (25)
Much worse	14 (14)	17 (21)	37 (18)	68 (18)
Adjusted OR (95% CI)	Ref	1.20 (0.62, 2.30)	0.98 (0.58, 1.67)	N/A
Watering of the eyes				
Not applicable	41 (42)	24 (30)	58 (28)	123 (32)
Much better	0 (0)	1 (1)	1 (1)	2 (1)
Somewhat better	3 (3)	1 (1)	8 (4)	12 (3)
No change	35 (36)	31 (39)	88 (42)	154 (40)
Somewhat worse	15 (16)	16 (20)	39 (19)	70 (18)
Much worse	3 (3)	7 (9)	17 (8)	27 (7)

(*continued on next page*)

Table 2 (*continued*)

Eye strain-related symptom	MILD dry eye (N = 97) n (%)	MODERATE dry eye (N = 80) n (%)	SEVERE dry eye (N = 211) n (%)	ALL Respondents (N = 388) n (%)
Adjusted OR (95% CI)	Ref	1.43 (0.63, 3.22)	1.25 (0.64, 2.46)	N/A
Redness of the eyes				
Not applicable	17 (18)	14 (18)	36 (17)	67 (17)
Much better	1 (1)	0 (0)	6 (3)	7 (2)
Somewhat better	7 (7)	2 (3)	7 (3)	16 (4)
No change	40 (41)	33 (41)	90 (43)	163 (42)
Somewhat worse	26 (27)	20 (25)	49 (23)	95 (25)
Much worse	6 (6)	11 (14)	23 (11)	40 (10)
Adjusted OR (95% CI)	Ref	1.47 (0.74, 2.91)	1.04 (0.59, 1.81)	N/A
Tiredness/fatigue of the eyes				
Not applicable	3 (3)	2 (3)	7 (3)	12 (3)
Much better	3 (3)	0 (0)	8 (4)	11 (3)
Somewhat better	6 (6)	5 (6)	11 (5)	22 (6)
No change	26 (27)	14 (18)	56 (27)	96 (25)
Somewhat worse	36 (37)	32 (40)	60 (28)	128 (33)
Much worse	23 (24)	27 (34)	69 (33)	119 (31)
Adjusted OR (95% CI)	Ref	1.70 (0.85, 3.40)	0.96 (0.56, 1.63)	N/A
Eye pain				
Not applicable	32 (33)	16 (20)	27 (13)	75 (19)
Much better	0 (0)	0 (0)	9 (4)	9 (2)
Somewhat better	6 (6)	1 (1)	10 (5)	17 (4)
No change	30 (31)	19 (24)	81 (38)	130 (34)
Somewhat worse	24 (25)	27 (34)	49 (23)	100 (26)
Much worse	5 (5)	17 (21)	35 (17)	57 (15)
Adjusted OR (95% CI)	Ref	2.57 (1.22, 5.41)*	1.00 (0.56, 1.81)	N/A
Difficulty keeping eyes open because of symptoms				
Not applicable	35 (36)	18 (23)	42 (20)	95 (25)
Much better	0 (0)	0 (0)	3 (1)	3 (1)
Somewhat better	4 (4)	2 (3)	8 (4)	14 (4)
No change	27 (28)	23 (29)	81 (39)	131 (34)
Somewhat worse	24 (25)	22 (28)	44 (21)	90 (23)
Much worse	7 (7)	15 (19)	33 (16)	55 (14)
Adjusted OR (95% CI)	Ref	1.60 (0.76, 3.38)	0.89 (0.48, 1.64)	N/A
Blurry vision				
Not applicable	24 (25)	13 (16)	29 (14)	66 (17)
Much better	0 (0)	1 (1)	1 (1)	2 (1)
Somewhat better	2 (2)	2 (3)	6 (3)	10 (3)
No change	20 (21)	22 (28)	69 (33)	111 (29)
Somewhat worse	38 (39)	24 (30)	57 (27)	119 (31)
Much worse	13 (13)	18 (23)	49 (23)	80 (21)
Adjusted OR (95% CI)	Ref	0.68 (0.33, 1.42)	0.59 (0.32, 1.07)	N/A
Fluctuating vision				
Not applicable	37 (38)	18 (23)	40 (19)	95 (24)
Much better	0 (0)	0 (0)	1 (1)	1 (0)
Somewhat better	1 (1)	3 (4)	5 (2)	9 (2)
No change	28 (29)	19 (24)	71 (34)	118 (30)
Somewhat worse	23 (24)	23 (29)	60 (28)	106 (27)
Much worse	8 (8)	17 (21)	34 (16)	59 (15)
Adjusted OR (95% CI)	Ref	1.51 (0.72, 3.18)	1.09 (0.59, 2.00)	N/A
Need to increase font size when reading				
Not applicable	21 (22)	12 (15)	30 (14)	63 (16)
Much better	0 (0)	0 (0)	1 (1)	2 (1)
Somewhat better	0 (0)	1 (1)	2 (1)	2 (1)
No change	27 (28)	27 (34)	80 (38)	134 (35)
Somewhat worse	36 (37)	27 (34)	58 (28)	121 (31)
Much worse	13 (13)	13 (16)	40 (19)	66 (17)
Adjusted OR (95% CI)	Ref	0.87 (0.43, 1.75)	0.58 (0.33, 1.03)	N/A
Need to brighten screen/room when reading				
Not applicable	18 (19)	10 (13)	31 (15)	59 (15)
Much better	0 (0)	0 (0)	1 (1)	1 (0)
Somewhat better	3 (3)	3 (4)	1 (1)	7 (2)
No change	34 (35)	36 (45)	92 (44)	162 (42)
Somewhat worse	30 (31)	22 (28)	48 (23)	100 (26)
Much worse	12 (12)	9 (11)	38 (18)	59 (15)
Adjusted OR (95% CI)	Ref	0.64 (0.32, 1.27)	0.70 (0.40, 1.23)	N/A
Eye symptoms interfered with screen use, reading, or work				
Not applicable	20 (21)	9 (11)	17 (8)	46 (12)
Much better	0 (0)	2 (3)	3 (1)	5 (1)
Somewhat better	2 (2)	2 (3)	9 (4)	13 (3)
No change	30 (31)	20 (25)	72 (34)	122 (31)
Somewhat worse	31 (32)	30 (38)	61 (29)	122 (31)
Much worse	14 (14)	17 (21)	49 (23)	80 (21)
Adjusted OR (95% CI)	Ref	1.34 (0.66, 2.71)	0.87 (0.50, 1.52)	N/A
Headache because of eye symptoms				
Not applicable	29 (30)	20 (25)	42 (20)	91 (24)
Much better	0 (0)	0 (0)	6 (3)	6 (2)
Somewhat better	3 (3)	0 (0)	3 (1)	6 (2)
No change	36 (37)	22 (28)	81 (38)	139 (36)
Somewhat worse	22 (23)	21 (26)	54 (26)	97 (25)
Much worse	7 (7)	17 (21)	25 (12)	49 (13)
Adjusted OR (95% CI)	Ref	2.34 (1.11, 4.90)*	1.15 (0.64, 2.09)	N/A
Difficulty concentrating because of eye symptoms				
Not applicable	19 (20)	9 (11)	33 (16)	61 (16)
Much better	0 (0)	0 (0)	4 (2)	4 (1)
Somewhat better	4 (4)	3 (4)	7 (3)	14 (4)
No change	37 (38)	20 (25)	75 (36)	132 (34)
Somewhat worse	28 (29)	31 (39)	54 (26)	113 (29)
Much worse	9 (9)	17 (21)	38 (18)	64 (17)
Adjusted OR (95% CI)	Ref	2.79 (1.37, 5.66)*	1.15 (0.64, 2.09)	N/A

• Odds ratio for each symptom was calculated as likelihood of rating symptom somewhat or much worse comparing respondents with moderate dry eye versus respondents with mild dry eye (3rd column) and comparing respondents with severe dry eye versus respondents with mild dry eye (4th column).
• All estimates and 95% confidence intervals (CIs) that are in bold font are statistically significant at the 95% confidence level.
• * = $P < 0.05$.
• Multivariable analysis that adjusts for age, sex, race, and employment status.

eye symptoms (OR = 2.41, 95% CI 1.16 to 5.03), and increased difficulty concentrating because of eye symptoms (OR = 2.90, 95% CI 1.41 to 5.95). Although not statistically significant, moderate dry eye was associated with worsening of other symptoms/functions during the pandemic, such as dryness of the eyes (OR = 1.69, 95% CI 0.87 to 3.27) and tiredness/fatigue of the eyes (OR = 1.70, 95% CI 0.85 to 3.40). Respondents with moderate dry eye in the setting of Sjögren's were most affected by the pandemic with regards to worsening of symptoms: dryness of the eyes (OR = 1.82, 95% CI 0.87 to 3.82) and tiredness/fatigue of the eyes (OR = 1.96, 95% CI 0.89 to 4.33).

Changes in reading efficiency and overall assessment of eyes

Moderate dry eye was associated with the greatest worsening of reading efficiency and poorest overall self-assessment of eyes during the pandemic, and these associations held even for respondents with Sjögren's. Respondents with moderate dry eye were more likely than respondents with mild dry eye to note that reading a document from beginning to end took longer during the pandemic than before (OR = 2.35, 95% CI 1.25 to 4.44) (Table 3). In addition, respondents with moderate dry eye were approximately twice as likely as respondents with mild dry eye to assess their eyes overall as worse during the pandemic than before (OR = 1.97, 95% CI 0.96 to 4.04). Respondents with moderate dry eye in the setting of Sjögren's had the greatest worsening (OR = 2.54, 95% CI 1.09 to 5.93).

Table 3
Change in reading efficiency and overall assessment of eyes among all survey participants and association with dry eye disease severity.

Aspect of reading	MILD dry eye (N = 97) n.(%)		MODERATE dry eye (N = 80) n.(%)		SEVERE dry eye (N = 211) n (%)		ALL Respondents (N = 388) n.(%)	
Time it takes to read a document from beginning to end								
Much shorter during pandemic	0	(0)	0	(0)	1	(1)	1	(0)
Somewhat shorter during pandemic	4	(4)	2	(3)	13	(6)	19	(5)
No change	52	(54)	29	(36)	111	(53)	192	(50)
Somewhat longer during pandemic	33	(34)	40	(50)	64	(30)	137	(35)
Much longer during pandemic	8	(8)	9	(11)	22	(10)	39	(10)
Adjusted OR (95% CI)	Ref		2.35 (1.25, 4.44)		0.87 (0.52, 1.44)		N/A	
Amount of time during which you can read (anything) without taking a break								
Much longer during pandemic	2	(2)	2	(3)	4	(2)	8	(2)
Somewhat longer during pandemic	13	(13)	10	(13)	29	(14)	52	(13)
No change	48	(50)	36	(45)	101	(48)	185	(48)
Somewhat shorter during pandemic	23	(24)	24	(30)	53	(25)	100	(26)
Much shorter during pandemic	11	(11)	8	(10)	24	(11)	43	(11)
Adjusted OR (95% CI)	Ref		1.34 (0.71, 2.52)		0.99 (0.59, 1.68)		N/A	
Screen use-related work efficiency during the pandemic (versus before)								
Not applicable	37	(38)	28	(35)	59	(28)	124	(32)
Much better	3	(3)	2	(3)	8	(4)	13	(3)
Somewhat better	12	(12)	10	(13)	24	(11)	46	(12)
No change	18	(19)	11	(14)	53	(25)	82	(21)
Somewhat worse	17	(18)	23	(29)	46	(22)	86	(22)
Much worse	10	(10)	6	(8)	21	(10)	37	(10)
Adjusted OR (95% CI)	Ref		1.44 (0.65, 3.16)		0.90 (0.48, 1.68)		N/A	
Comparison of eyes overall during the pandemic								
Better	10	(10)	7	(9)	32	(15)	49	(13)
No change	25	(26)	11	(14)	52	(25)	88	(23)
Worse	62	(64)	62	(78)	127	(60)	251	(65)
Adjusted OR (95% CI)	Ref		1.97 (0.96, 4.04)		0.80 (0.47, 1.36)*		N/A	

• Odds ratio for each comparison calculated as likelihood of below dotted line versus above dotted line comparing respondents with moderate dry eye versus respondents with mild dry eye (3rd column) and comparing respondents with severe dry eye versus respondents with mild dry eye (4th column).
• All estimates and 95% confidence intervals (CIs) that are in bold font are statistically significant at the 95% confidence level.
• * = $P < 0.05$.
• ** = $P < 0.001$.
• Multivariable analysis that adjusts for age, sex, race, and employment status.

Changes in use of dry eye-related treatments

Dry eye severity was not associated with increased dry-eye related treatment use. However, respondents with severe dry eye were considerably more likely than respondents with mild dry eye to experience a change in *access* to treatments during the pandemic (OR = 2.62, 95% CI 1.36 to 5.03) (Table 4). Sjögren's status did not modify this association. Table 5 characterizes the changes in the respondents who reported experiencing a change. Commonly-noted changes included unavailability of over-the-counter products (33%), unavailability of prescription treatments or devices (23%), unavailability of in-office treatments (14%), and the lack of time to pursue treatments (13%).

Discussion

In this large-scale online survey of patients with dry eye during the early stages of the COVID-19 pandemic, we found that screen/reading time generally doubled and almost half of the respondents experienced a decrease in work efficiency. In addition, dry eye discomfort symptoms worsened during the pandemic, which was greatest in those with moderate dry eye, particularly in the setting of Sjögren's syndrome. Respondents with severe dry eye had the greatest difficulty with access to dry-eye related treatments.

COVID-19 and dry eye-related societal burden

The societal economic burden due to dry eye was high even before the COVID-19 pandemic (more than $50 billion a year annually in the U.S.[3,19]. Although the current study is cross-sectional, it suggests that the increased eye strain during the pandemic might further increase this societal economic burden. Patients with moderate dry eye, especially those with Sjögren's, may be experiencing the impact of increased eye strain to a greater extent than individuals with mild dry eye. The most impacted symptoms—increased eye pain, headache because of eye symptoms, and difficulty concentrating because of eye symptoms—very likely contributed to more respondents with moderate dry eye reporting lower work efficiency during the pandemic than before. Other related factors potentially lowering work efficiency may include increased time needed to read a document from beginning to end, feeling that one's eyes are worse overall, and experiencing reduced access to much-needed treatments. However, it is worth noting that the association between dry eye and worsening of symptoms was not statistically significant for all symptoms, such as foreign body sensation and burning of the eyes.

The eye strain and its consequences might have been even stronger had desktop computer use increased during the pandemic. It has been hypothesized that reading on desktop computers involves a wider palpebral aperture (increased exposed ocular surface area), which accelerates tear film evaporation and increases symptoms of dry eye [20–22]. This is unlike reading on laptop computers, hand-held devices, and paper, which are typically viewed in downgaze. Thus, the negative effects of visual strain on individuals with dry eye in the current study may have been ameliorated by the lack of an increase in desktop use.

Our findings are consistent with prior studies demonstrating that dry eye is associated with reductions in concentration [23] and work productivity.[24-30] During the COVID-19 pandemic, various societal disparities, such as by socioeconomic position, race, and employment type, have been uncovered and/or amplified [31–35]. Our results suggest that the pandemic may be impacting individuals with moderate dry eye to a greater extent than those with mild dry eye in terms of function and employment. Dry eye status may prove to be yet another societal disparity amplified by the pandemic.

Reduced access to much-needed dry eye-related treatments was also noted in this study. Such a reduction was most pronounced in patients

Table 4
Change in access and use of dry eye-related treatments among all survey participants and association with dry eye severity.

Comparison of dry eye-related treatment use (During pandemic versus before)	MILD dry eye (N = 97) n (%)	MODERATE dry eye (N = 80) n (%)	SEVERE dry eye (N = 211) n (%)	ALL Respondents (N = 388) n (%)
Experienced a change in access to dry-eye related treatments during the pandemic				
No	82 (85)	67 (84)	146 (69)	295 (76)
Yes	15 (15)	13 (16)	65 (31)	93 (24)
Adjusted OR (95% CI)	Ref	1.11 (0.48, 2.58)	**2.62 1.36, 5.03)***	N/A
Use of over-the-counter lubricant, drops, gels, or ointments				
Not applicable	12 (12)	8 (10)	21 (10)	41 (11)
Much less	1 (1)	0 (0)	4 (2)	5 (1)
Somewhat less	8 (8)	5 (6)	15 (7)	28 (7)
No change	19 (20)	14 (18)	60 (28)	93 (24)
Somewhat more	33 (34)	27 (34)	54 (26)	114 (29)
Much more	24 (25)	26 (33)	57 (27)	107 (28)
Adjusted OR (95% CI)	Ref	1.30 (0.63, 2.68)	0.67 (0.38, 1.17)	N/A
Use of warm or cold compresses				
Not applicable	62 (64)	31 (39)	60 (28)	153 (39)
Much less	0 (0)	0 (0)	2 (1)	2 (1)
Somewhat less	4 (4)	1 (1)	3 (1)	8 (2)
No change	12 (12)	22 (28)	74 (35)	108 (28)
Somewhat more	11 (11)	15 (19)	41 (19)	67 (17)
Much more	9 (8)	11 (14)	31 (15)	50 (13)
Adjusted OR (95% CI)	Ref	1.05 (0.42, 2.64)	0.78 (0.36, 1.71)	N/A
Taking breaks to rest my eyes				
Not applicable	10 (10)	7 (9)	18 (9)	35 (9)
Much less	1 (1)	1 (1)	7 (3)	9 (2)
Somewhat less	8 (8)	2 (3)	9 (4)	19 (5)
No change	11 (11)	8 (10)	54 (26)	73 (19)
Somewhat more	39 (40)	36 (45)	58 (28)	133 (34)
Much more	28 (29)	26 (33)	65 (31)	119 (31)
Adjusted OR (95% CI)	Ref	1.64 (0.69, 3.88)	0.47 (0.26, 0.88)	N/A
Use of prescription eye drops, gels, or ointments				
Not applicable	97 (100)	0 (100)	52 (25)	149 (38)
Much less	N/A	2 (3)	1 (1)	3 (1)
Somewhat less	N/A	0 (0)	6 (3)	6 (2)
No change	N/A	42 (53)	82 (39)	124 (32)
Somewhat more	N/A	23 (29)	31 (15)	54 (14)
Much more	N/A	13 (16)	39 (19)	52 (13)
Adjusted OR (95% CI)	N/A	Ref	0.95 (0.54, 1.67)	N/A
Use of dry eye goggles/glasses				
Not applicable	97 (100)	80 (100)	47 (22)	224 (58)
Much less	N/A	N/A	5 (2)	5 (1)
Somewhat less	N/A	N/A	4 (2)	4 (1)
No change	N/A	N/A	93 (44)	93 (24)
Somewhat more	N/A	N/A	24 (11)	24 (6)
Much more	N/A	N/A	38 (18)	38 (10)
Use of special contact lenses for dry eye				
Not applicable	97 (100)	80 (100)	116 (55)	293 (76)
Much less	N/A	N/A	2 (1)	2 (1)
Somewhat less	N/A	N/A	1 (1)	1 (0)
No change	N/A	N/A	77 (37)	77 (20)
Somewhat more	N/A	N/A	7 (3)	7 (2)
Much more	N/A	N/A	8 (4)	8 (2)
Use of in-office treatments (e.g., Lipiflow®, Intense Pulsed Light [IPL] therapy, Meibomian gland probing, Blephex®)				
Not applicable	97 (100)	80 (100)	135 (64)	312 (80)
Much less	N/A	N/A	4 (2)	4 (1)
Somewhat less	N/A	N/A	2 (1)	2 (1)
No change	N/A	N/A	63 (30)	63 (16)
Somewhat more	N/A	N/A	N/A	2 (1)
Much more	N/A	N/A	N/A	5 (1)
Use of TrueTear®				
Not applicable	97 (100)	80 (100)	146 (69)	323 (83)
Much less	N/A	N/A	1 (1)	1 (0)
Somewhat less	N/A	N/A	1 (1)	1 (0)
No change	N/A	N/A	47 (12)	47 (12)
Somewhat more	N/A	N/A	8 (2)	8 (2)
Much more	N/A	N/A	8 (2)	8 (2)

- All estimates and 95% confidence intervals (CIs) that are in bold font are statistically significant at the 95% confidence level.
- * = $P < 0.05$.
- ** = $P < 0.001$.
- Multivariable analysis that adjusts for age, sex, race, and employment status.

with severe dry eye, for whom access to in-office treatments lapsed during the pandemic. As of writing, the current trends in COVID-19 prevalence and mortality suggest that COVID-19 is here to stay. It remains unclear as to when society will return to 'normal,' such as to pre-pandemic levels of dry-related treatments. Moreover, it is possible that after the pandemic, some segments of the population may, for various reasons, choose to continue working from home. Given these eventualities as well as the contemporaneous advances in technology and remote working and educational capabilities that contribute to increased screen time, increased eye strain will likely continue to be a public health problem [36,37].

The absence of greatly worsened symptoms, increased treatment use, or poor performance of eyes among respondents in the severe dry eye group (when compared with the mild dry eye group) is worthy of discussion. We believe two factors may have contributed to this. *First*, we classified respondents as having severe dry eye if they were using specialized treatments for dry eye, but not necessarily based on symptoms or clinical findings. Although some of these patients may have temporarily lost access to their treatments, they were likely under more effective long-term treatment and monitoring for their dry eye. On the other hand, we surmise that respondents in the moderate dry eye group reported generally poorer outcomes in this survey because many may have been inadequately treated for their dry eye (by definition, they were not on specialized treatments). The impact of such inadequate treatment was likely exacerbated in the context of increased screen time and other forms of eye strain during the pandemic. *Second*, our survey instrument was designed to capture *change* in symptoms during the pandemic. We did not ask respondents about the severity of their symptoms at baseline (i.e., before the pandemic). It is possible that patients with severe dry eye had very high levels of symptoms before the pandemic and these remained very high during the pandemic. Such a "ceiling effect" may have contributed to relatively fewer patients with severe dry eye not reporting worsening of symptoms during the pandemic.

Strengths and limitations

First, to our knowledge, this is the first study to document the impact of eye strain on self-reported dry eye-related symptomatology, visual function, and treatment usage during the COVID-19 pandemic. *Second*, the survey had a high completion rate (68% of individuals who clicked through to the survey information page). *Third*, the sample size was large (388 individuals) and included respondents with dry eye of different severities. *Fourth*, the study raises early flags of a likely increase in the societal burden of dry eye in the months and years to come due to

Table 5
Ways in which access to regular dry-eye related treatments changed during the pandemic.

Ways in which dry eye-related treatment changed during the pandemic[a]	Respondents with MILD dry eye who lost access (N = 15) n (%)	Respondents with MODERATE dry eye who lost access (N = 13) n (%)	Respondents with SEVERE dry eyewho lost access (N = 65) n (%)	ALL Respondentswho lost access (N = 93) n (%)
The over-the-counter products that I needed were not available.	8 (53)	3 (23)	20 (31)	31 (33)
The over -the-counter products that I needed were available, but I could not afford them.	2 (13)	0 (0)	3 (5)	5 (5)
The prescription treatments or devices that I needed were not available.	N/A	4 (31)	17 (26)	21 (23)
The prescription treatments or devices that I needed were available, but I could not afford them.	N/A	1 (8)	10 (15)	11 (12)
The in-office treatments that I needed were not available.	N/A	N/A	13 (20)	13 (14)
The in-office treatments that I needed were available, but I could not afford them.	N/A	N/A	2 (3)	2 (2)
I did not have the time to pursue the treatments that I needed.	4 (27)	2 (15)	6 (9)	12 (13)
Other	1 (7)	3 (23)	3 (5)	7 (8)

N/A = not applicable.
[a] Respondents could select more than one response.

the pandemic. This increase in burden could be even more substantial if, as discussed, segments of the population continue working from home.

Our study is not without limitations. *First*, we relied on respondent self-report for all information gathered, including screen/reading time, symptoms, physician diagnoses, and treatments. Respondents might have mischaracterized some of this information. Also, we categorized respondents into dry eye severity categories according to the treatments they reported receiving, assuming that treating physicians adhered to TFOS DEWS II guidelines. Relatedly, for various questions, we asked respondents to recall information from the previous week (during the pandemic) and from more than 3 months earlier (before the pandemic). This may have been recalled incorrectly in some cases. Such incorrect recall may have led to 'recall bias' if, for example, respondents with more severe forms of dry eye may have remembered (or made greater efforts to remember) information than did respondents with mild dry eye. The impact of this potential bias, an example of differential misclassification, could be that the ORs could go in either direction relative to the truth (i.e., they could be stronger or weaker than the truth) [38]. This may, in part, explain why we did not observe sizeable and/or statistically-significant associations between dry eye and changes in some symptoms. *Second*, we disseminated the survey in June–July 2020, after strict lock-down restrictions were partially lifted in some locations. It is likely that respondents were spending less time at home than they had been during the peak of those restrictions; thus, part of the impact of eye strain on visual symptoms and function might have dissipated by the time of the survey. This may have also contributed to why we did not observe sizeable and/or statistically-significant associations between dry eye and changes in some symptoms. *Third*, a sizeable proportion of the respondent population in this study (61% overall) reported having received a diagnosis of Sjögren's. This is because the Sjögren's Foundation was one of the audiences to which we disseminated the survey. This may limit the applicability of the study results to very broad audiences. *Finally*, regrettably, we did not explore the effect of facemask wearing on dry eye. Recent studies during later stages of the COVID-19 pandemic have suggested that facemask use may be associated with increased ocular dryness, discomfort, and irritation [39,40].

In conclusion, during the COVID-19 pandemic, individuals with moderate dry eye, particularly those with Sjögren's, may be disproportionately experiencing the consequences of increased eye strain. Individuals with severe dry eye may be disproportionately experiencing reduced access to dry eye-related treatments. Taken together, these experiences may be having a considerably negative impact on the work efficiency of patients with dry eye. This represents an important disparity for the current pandemic as well as for future scenarios of increased eye strain.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jtos.2021.06.004.

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