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Original article

Presbyopia progression during the pandemic of COVID-19: Accelerated senescence?

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Abstract

***Objective*:** To compare the degree of presbyopia in ophthalmology patients before and after the 2020 COVID-19 pandemic.
***Methods*:** Near add power measurements and dry eye-related tests were performed on 349 ophthalmology patients aged 40-55 years from 2017 to 2022, and the presence of common subjective symptoms (fatigue, blurred vision, glare, dryness, discomfort, and pain) was interviewed. The subjects were first-visit patients with biocular phakic and best corrected visual acuity of 0.8 or better in both eyes. Patients with glaucoma, ocular fundus diseases, and those within one month after ophthalmic surgery were excluded.
***Results*:** From 2017-2019, near add power was strongly correlated with age ($\beta = 0.777$, $p < 0.001$), and the estimated age of onset of presbyopia was 36.5 years, which decreased to 25.5 years in 2020 and recovered to 32.5 years in 2021. Subjective symptoms continued to worsen in both 2020 and 2021. Tear film breakup time, a dry eye-related test, and corneal damage, remained unchanged after 2020.
***Conclusion*:** The COVID-19 pandemic reduced the age of onset of presbyopia in 2020, indicating a decline in amplitude of accommodation, which recovered in 2021. Accommodation fatigue from increased near work (work that requires prolonged close-up viewing) due to increased telework and stress from changes in lifestyle and work environment are thought to be the main causes, however, we also consider the possibility that COVID-19 may accelerate aging.

***KEY WORDS*:** COVID-19, aging, presbyopia, eye strain, dry eye

Introduction

In March 2020, the World Health Organization declared COVID-19 a pandemic[1] and a state of emergency was declared in Japan in April. This led to a rapid change in work and lifestyle, with voluntary refraining from going out of the house, encouraging telework (telecommuting), and switching to e-learning and distance learning[2]. Along with reports of ocular complications from the virus[3], survey results reported increased VDT (visual display terminal) viewing time, eye strain and dry eyes[4-8], and recently worsening myopia has also been reported in other countries[9]. However, there are few reports of studies examining changes in general ocular symptoms and ophthalmologic examinations before and after the pandemic.

The current study focused on subjective symptoms, dry eye-related corneal and lacrimal tests, and near add power, which indicates the degree of presbyopia, in first-visit ophthalmology patients before and after the pandemic declaration. Presbyopia makes it difficult for people to focus on near objects as they age and interferes with their daily lives[10]. In today's society, the need for near vision is increasing in both work and daily life, and there are far more important sources of visual information in the near position than in the far position. Moreover, presbyopia is becoming a serious social problem due to the super-aging of society and the use of smartphones and other digital devices. Presbyopia is a deterioration of the accommodative function for focusing, and among the ocular tissues involved in accommodation, the lens and pupil play a major role in presbyopia.

When we want to see near, the pupil contracts and the ciliary muscle contracts to thicken the lens to focus on the near. The ability to adjust the pupil decreases with age from around age 10, and most people reach a plateau of presbyopia

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by age 60. The average age at which near vision correction becomes necessary is 48 years [11]. The most common method of correcting presbyopia is eyeglasses, in which lenses are used to correct for the lack of accommodation, which is the near add power. Bifocal contact lenses are also used, and in surgical treatment, a bifocal or multifocal intraocular lens is inserted during cataract surgery to treat presbyopia. In drug therapy, the effectiveness of anti-cataract drugs has been reported [12] and anti-oxidative/anti-glycative foods may be also beneficial to presbyopia via anti-cataract effect [13, 14]. Eye exercise to supress the progression of presbyopia has also been reported [15].

Presbyopia has a very large target population and includes the working age population, so the impact on their lives and the economy is very large. It is estimated that 1.8 billion people, or 25% of the world's population, have presbyopia, and 830 million people have difficulty performing near work (work that requires prolonged close-up viewing) due to inadequate correction [16]. Other reports have shown that up to 90% of people over the age of 35 had presbyopia symptoms, and presbyopia reduced quality of life scores by up to 22% [17]. Twelve percent of people with presbyopia needed assistance in daily life, and had a tendency toward depression and decreased self-confidence. The loss of productivity due to presbyopia in the under-50 age group was $11 billion worldwide, equivalent to 0.016% of the global gross domestic product in 2011.

In our prior study, 219 healthy subjects between the ages of 40 and 59 years were measured for near add power, and the results showed no difference between men and women, and no difference in the progression of presbyopia between them [11]. However, there was a significant difference in the power of contact lenses for distance vision, with women using an average of 0.25 D lower correction to see both distance and near vision. According to the results of a web-based survey of healthy subjects aged 40 to 59 years, presbyopia symptoms developed more strongly and earlier in men, and men started using reading glasses an average of 9 months earlier than women (47.4 years for men and 48.2 years for women).

Men who used reading glasses had lower well-being, men who were aware of presbyopia symptoms had poorer sleep, and this was not the case for women. It is assumed that the reason why men suffer more from presbyopia symptoms is because men have more opportunities to look at distant objects and women at near objects in their work and daily life. Recent studies have shown that near vision impairment due to presbyopia occurs from the stage when binocular near visual acuity is as good as 1.0, so it is necessary to establish new diagnostic criteria for presbyopia in order to diagnose presbyopia and provide appropriate therapeutic intervention [18].

The COVID-19 pandemic has led to widespread telecommuting and distance learning, resulting in an increase in the amount of time spent working on the web using VDT, and a larger number of people are complaining of eye strain. We previously conducted a study of 339 ophthalmology outpatients aged 40-55 years in 2017, 2019, and 2020-2021, before and after the pandemic, to determine the the degree of presbyopia (near add power) increased after the pandemic [19]. The degree of presbyopia usually shows a strong correlation with age, but after the pandemic declaration, the correlation was weaker. Since then, there have been no reports examining the relationship between the pandemic and eye strain or presbyopia. Our study therefore aimed to compare the symptoms and clinical examination results of ophthalmology patients before and after the pandemic declaration, and to examine the course of the disease after the declaration in 2020 and 2021.

Methods

The study was a retrospective, cross-sectional cohort study and was approved by the Institutional Review Board of Keio University School of Medicine, Tsukuba Central Hospital, and Kanagawa Medical Association. Consent of study participants was obtained on an opt-out basis, and the study was conducted in compliance with the Declaration of Helsinki and ethical guidelines for clinical research.

The subjects were patients who visited Otake Eye Clinic (Yamato, Kanagawa, Japan) and Tsukuba Central Hospital (Ushiku, Ibaraki, Japan) from 2015 to 2021 and met the selection criteria. The selection criteria were first-visit patients with binocular phakic, age between 40 and 55 years, and with corrected visual acuity of 0.8 or better. Exclusion criteria were glaucoma, vitreoretinal disease, optic nerve disease, acute ocular disease occurring within 2 weeks, and ocular surgery within one month of data collection. The reason for selecting this age range is that presbyopia generally progresses linearly during this period, and it is possible to examine the effects of various conditions. Glaucoma was excluded from this study, since glaucoma eye drops have the effect of decreasing accommodation [20].

Examinations included a corrected visual acuity and a near add power test (using the New Standard Near Vision Chart manufactured by Handaya, Tokyo, Japan). Corneal examinations included fluorescein corneal staining (negative staining was classified as 0, followed by 1 and 2 in order of degree) and tear film breakup time (BUT). Symptoms were evaluated by asking about the presence or absence of six common symptoms (dry sensation, foreign body sensation, painful or sore eyes, ocular fatigue, blurred vision, and sensitivity to blight light) extracted from the DEQS (Dry Eye-related Quality-of-Life Score) [21], a standardized questionnaire for dry eyes.

Statistical analysis was performed by dividing cases into three groups by year of examination (2017-2019, 2020, and 2021) and comparing pre- and post-pandemic cases using the Mann-Whitney test with Bonferroni correction, and chi-square test for frequency of symptoms. Correlation analysis with age in each group was performed for near add power, and the correlation coefficients and presbyopia progression were compared before and after the pandemic. Regression equations were obtained using the least squares method. Statistical software StatFlex (Artec, Osaka, Japan) was used.

Results

The number of cases in each group, gender, refraction, near add power, progression of presbyopia, and correlation coefficient between age and near add power are shown in

Table 1. Spherical equivalent became more myopic with each year of age. The mean near add power for the entire subject population was 1.54 ± 0.67 D in 2017-2019 before the pandemic, then 1.79 ± 0.55 D in 2020 ($p = 0.003$, vs 2017-2019), and 1.71 ± 0.65 D ($p = 0.039$).

The degree of presbyopia progression by age increased in 2020 compared to 2019 ($p < 0.001$) and recovered in 2021 ($p = 0.104$). The correlation coefficient with age also decreased in 2020 ($p < 0.001$), then recovered in 2021 ($p = 0.106$). Scatter plots and regression lines for the three groups are shown in *Fig. 1*, where the x-intercept at $y = 0$ can be considered the approximate age of onset of near add power, 36.5 years in 2017-2019 (regression equation; $y = 0.128x - 4.70$), 25.5 years in 2020 ($y = 0.074x - 1.89$, $p < 0.001$, vs 2017-2019) and 32.5 years in 2021 ($y = 0.104x - 3.39$, $p = 0.074$). After the pandemic declaration, the age of presbyopia onset shifted significantly to the younger side and recovered in 2021.

After the pandemic, subjective symptoms generally worsened in 2020 and 2021, except for eye pain, which did not differ significantly (*Table 2, Fig. 2*). Both BUT and corneal staining score did not change before and after the pandemic.

Table 1. Refraction and presbyopia status.

Year	2017-2019	2020	2021	P value (2017-2019 vs 2020)	P value (2017-2019 vs 2021)
n	225	62	62		
Age	48.5 ± 4.1	49.5 ± 3.7	48.9 ± 4.7	0.032*	0.257
Sex (% male)	26.2	35.3	23.0	0.152	0.625
Spherical Equivalent (D)	−3.80 ± 3.12	−2.81 ± 2.97	−2.52 ± 3.11	0.011*	0.002*
Near add power (D)	1.54 ± 0.67	1.79 ± 0.55	1.71 ± 0.65	0.003*	0.039*
Progression of presbyopia (D/y)	0.13	0.07	0.10	<0.001*	0.104
Standardized correlation coefficient between age and near add power	0.787	0.503	0.687	<0.001*	0.106
Estimated age at zero near add power (y)	36.5	25.5	32.5	<0.001*	0.074

*$p < 0.05$, calculated by Mann Whitney U test with Bonferroni correction except for sex, which was analyzed with chi square test.

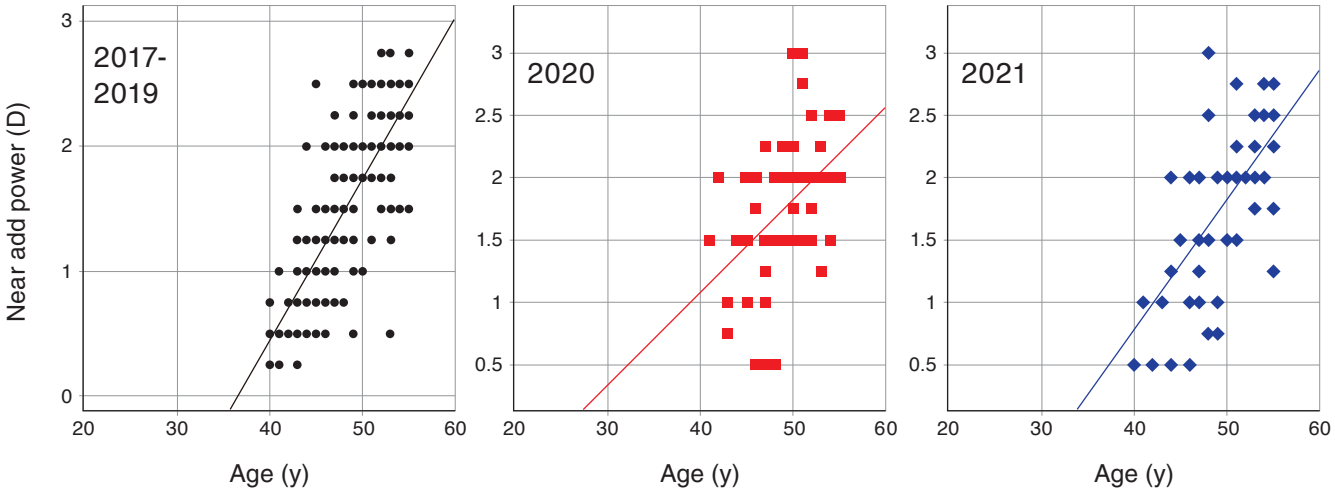

***Fig. 1.* Scatter plots of near add power and age in each group.**

Scatter plots and regression lines of patient age and near add power for each year are shown. The x-intercept at $y = 0$ can be considered the approximate age of occurrence of near add power, shifting significantly to the younger side after the pandemic declaration and recovering in 2021.

Table 2. The prevalence of dry eye-related symptoms and corneal signs.

Year and prevalence (%)	2017-2019	2020	2021	P value (2017-2019 vs 2020)	P value (2017-2019 vs 2021)
Eye fatigue	46.6	46.3	52.5	0.863	0.445
Blurring	43.1	43.3	54.2	0.964	0.131
Photophobia	18.3	23.9	23.7	0.309	0.309
Dryness	22.1	34.3	39.0	0.103	0.059
Discomfort	16.8	20.9	25.4	0.464	0.160
Pain	10.0	22.4	11.9	0.011*	0.657
Tear break-up time	2.99 ± 2.04	2.73 ± 2.22	3.00 ± 2.22	0.723	1.000
Positive corneal staining	0.29 ± 0.57	0.21 ± 0.54	0.28 ± 0.52	0.558	1.000

*p < 0.05, chi squared test and Mann-WhitneyU test with Bonferroni correction

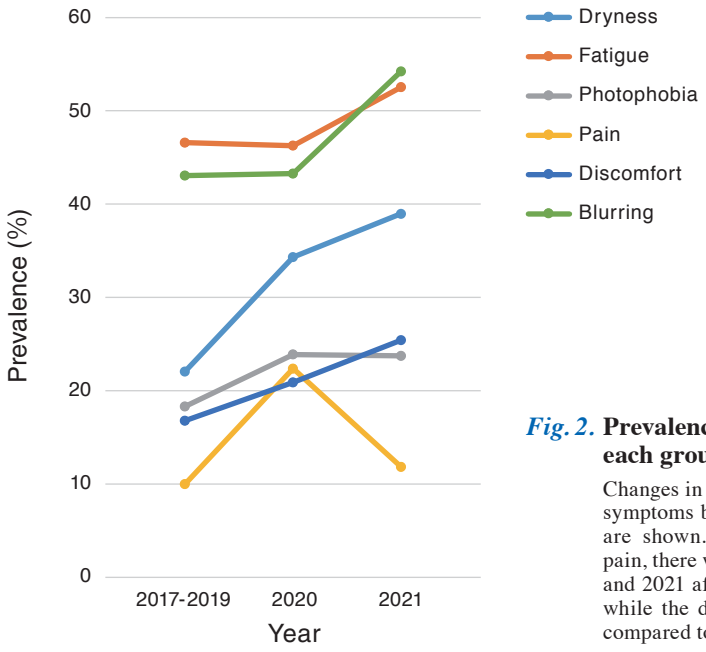

***Fig. 2.* Prevalence of ocular symptom in each group.**

Changes in the frequency of major ocular symptoms before and after the pandemic are shown. With the exception of eye pain, there was a worsening trend in 2020 and 2021 after the pandemic declaration, while the difference was not significant compared to 2017-2019.

Discussion

The present study showed that the degree of presbyopia worsened after the pandemic was declared. In other words, the age at which presbyopia began to require near correction was earlier, and this trend eased in 2021, one year after the pandemic was declared. The reasons for the increase in near add power after the pandemic declaration may be due to accommodation fatigue and stress associated with increased VDT viewing time. Studies have reported that stress increases pupil diameter and decreases amplitude of accommodation[22-24]. In particular, it is imagined that many people were anxious and stressed immediately after the pandemic was declared.

In general, there is a strong correlation between age and near add power, as in the pre-pandemic 2017-2019 values. Nevertheless, in 2020, the correlation varied. We speculate that the reason for this is that there are individual differences in ocular fatigue and stress-induced decline of accommodation under the pandemic.

The fact that the x-intercept of the regression line was as young as 25.5 years old indicates that there was a marked decline in the subject's overall amplitude of accommodation and age at which presbyopia began. By 2021, both the correlation coefficient and the x-intercept values were approaching pre-pandemic levels. This may mean that the target patients are becoming accustomed to their new lives and jobs, while the number of companies promoting telework continues to increase,

Nevertheless, it is worth noting that the pandemic significantly affected the accommodative function of the eye and accelerated the age of onset of presbyopia by 10 years. Besides the increase in near work and stress, there is also the possibility of an epigenetic aging-promoting effect of

COVID-19, since a certain percentage of the target patients are thought to have been COVID-19-infected [25,26]. Presbyopia is a typical aging phenomenon that progresses at a certain rate, and the fact that marked changes were observed after the pandemic this time may be a useful result in considering the systemic effects of this virus.

Subjective symptoms took a different course than presbyopia; they were worse in 2020 than in 2019, as expected, but the worsening trend continued in 2021. This may be due to the fact that presbyopia symptoms, eyestrain symptoms, and dry eye symptoms continued and that patients who had refrained from going out gradually began to see the doctor, which may have resulted in a change in the subject content [27].

There is concern that dry eye may increase during a pandemic due to stress and the constant wearing of masks [28,29]. Dry eye causes instability of the tear fluid layer on the ocular surface, resulting in a variety of symptoms including dryness, foreign body sensation, pain, fatigue, blurred vision, and photophobia [30,31]. Epidemiologically, the frequency of dry eye is higher in women and the elderly, while the incidence of dry eye has been increasing in recent years, as blinking is believed to worsen or develop when looking at digital screens. When the precorneal tear film, which is part of the optical system, is disrupted by dry eye, visual function is reduced, and higher order aberrations and reduced functional visual acuity have been reported [32-35]. Our study revealed that presbyopia progresses significantly faster in female dry eye patients [36], which may be related to the present results. Since the BUT, a major indicator of dry eye, did not change, it is possible that the accommodation fatigue due to increased near work may be a more significant factor in the deterioration of presbyopia at this time. On the other hand, some people find telecommuting stressful while others do not. The work environment also differs from that of those who go to work. With the advantages of free air conditioning and the ability to work without a mask, whether teleworking is a factor that aggravates dry eye needs further study.

Research limitation

First, the eye examination patients analyzed in this study may be biased toward those with severe symptoms to some extent. Especially after 2020, many patients who dared to visit a doctor because of concerns about their symptoms are included in this group, even though they are refraining from going out. If the general public aged 40-55 were included in the analysis, the impact of the pandemic could be more accurately assessed. Concurrently, during the period of the emergency declaration and "the Law for the Prevention of the Spread of Infectious Diseases", many people are likely to refrain from seeing a doctor, especially the elderly and patients with minor illnesses. The situation of consultations differs from that before the pandemic, which is also likely to be biased.

Second, we did not investigate previous infection associated with the pandemic or COVID-19 virus antibody levels, and the infection status of the subjects was unknown. Therefore, the effect of COVID-19 infection on presbyopia could not be examined in this study.

Third, further measurement of pupil diameter, which is significantly involved in accommodation, would allow accurate evaluation of presbyopia status. In addition, by listening to the duration of VDT viewing and the use of digital devices, it is possible to clarify the relationship between the near add power and the symptoms.

Conflict of interest declaration

The authors have no conflicts of interest to declare.

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