

Original

# Impact of lifestyle intervention on dry eye disease in office workers: a randomized controlled trial

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**Abstract: Objectives:** To evaluate the effects of a 2-month lifestyle intervention for dry eye disease in office workers. **Methods:** Prospective interventional study (randomized controlled study). Forty-one middle-aged Japanese office workers (men, 22; women, 19; 39.2±8.0 years) with definite and probable dry eye disease were enrolled and randomized to an intervention group (n = 22) and a control group (n = 19). The intervention aimed at modifying diet, increasing physical activity, and encouraging positive thinking. The primary outcome was change in dry eye disease diagnoses. Secondary outcome was change in disease parameters, including dry eye symptoms, as assessed using the Dry Eye-Related Quality of Life Score, corneal and conjunctival staining scores, tear break-up time, and Schirmer test results. **Results:** A total of 36 participants (intervention group, 17; control group, 19) completed the study. The number of definite dry eye disease diagnoses decreased from four to none ( $p = .05$ ), and the dry eye symptom score showed a significant decrease in the intervention group ( $p = .03$ ). In contrast, the corneal and conjunctival staining scores, tear break-up time, and Schirmer test results did not differ significantly between groups. **Conclusions:** The 2-month lifestyle intervention employed in this study improved dry eye disease status among office workers, with a considerable decrease in subjective symptoms. Lifestyle intervention may be a promising management option for dry eye disease, although further investigation of long-term effects are required.

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**Key words:** Dry eye, Lifestyle intervention, Office worker, Randomized controlled trial

## Introduction

The increasing prevalence of dry eye disease (DED) worldwide is an important public health problem, particularly in developed countries with advanced information technology<sup>1-3</sup>. One reason for the rapid increase in the number of DED cases over the last few years is believed to be prolonged visual display terminal (VDT) exposure caused by increased computer use. These changes in work and leisure activities have been accompanied by an increase in the number of reported symptoms of several health problems associated with VDT use. Eye problems, particularly DED, are a common cause of, or are at least associated with, ocular symptoms among office workers<sup>1,4,5</sup>.

Dry eye disease can be debilitating because it can impair visual function and cause difficulty in tasks requiring sustained visual concentration<sup>6</sup>. The condition can also have a negative impact on physical, social, and psychological health and negatively impact a patient's overall sense of well-being<sup>6,7</sup>. Therefore, measures to decrease the prevalence of DED in VDT users are important.

Recently, some studies have reported that tear secretion is associated with lifestyle<sup>8,9</sup>. For instance, decreased physical activity and sedentary behavior are associated with DED<sup>8</sup>, and metabolic syndrome is associated with decreased tear secretion<sup>9</sup>. Furthermore, decreased subjective happiness is reportedly associated with severe dry eye symptoms<sup>10</sup>. We recently reported that aerobic exer-

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Supplementary materials (Appendices) are available in the online version of this article.

cise increases tear secretion in mice with type 2 diabetes<sup>11</sup>.

Therefore, we hypothesized that lifestyle interventions, including those pertaining to physical activity, diet, and subjective happiness, may mitigate DED. We conducted this study to investigate whether a two-month lifestyle intervention can affect DED, the subjective happiness score, and/or the general health conditions of office workers.

## Methods

### *Design and participants*

This study was designed to evaluate whether 2 months of lifestyle education and intervention could decrease the rate of DED diagnosis among office workers who use VDT for more than 4 hours a day in Japan. Japanese office workers are generally at their desktop computers for 8 hours/day, and the average VDT time is 7.9 hours. In this study, office workers with definite or probable DED were randomized to either an intervention group (n = 22) or a control group (n = 19; Supplemental Fig. 1). Their group assignment was given to them in a sealed envelope.

We excluded workers who were already performing intense exercises or were dieting, workers undergoing DED treatment (eye drops or punctal plugs), workers who were pregnant or lactating, and workers with DED associated with cataract or glaucoma. Workers with severe cardiovascular, hepatic, or renal disease and/or cancer were also excluded, along with those who had participated in another clinical trial within the previous 3 months. Participants with data deemed inadequate by the principal investigator were also excluded.

### *Intervention*

Study interventions aimed at modifying diet, increasing physical activity, and encouraging positive thinking. The participants in the intervention group followed an educational program to encourage physical activity and healthy nutrition, and were asked to express their positive findings. Briefly, they were asked to enter their targeted food intake and pedometer data daily into self-monitored records. They were also asked to write about three of their most positive life experiences throughout the study period. The physical activity regime was based on the 2006 exercise guidelines of the Ministry of Health, Labour and Welfare of Japan. Each day, intervention group participants were encouraged to perform squats for 4 minutes, walk for 20 minutes, do stepping exercises for 10 minutes, bike for 15 minutes, lightly jog for 10 minutes, or run for 7-8 minutes to provide a conscious increase in physical activity. For healthy nutrition, subjects were instructed to consume foods with a low glycemic index and to decrease carbohydrate intake, paying careful attention to balance their food intake with fish and vegetables at

each meal. Additionally, participants were given a list of low glycemic index foods, and a low glycemic index lunch menu was added to the company cafeteria for participants during the course of the study.

### *Data collection*

During the week prior to subject group assignment, baseline data were collected, including food intake, exercise habits (using both a questionnaire and a pedometer), and subjective happiness. Control subjects were instructed to continue life as usual. No diet or exercise restrictions were placed during the study. Subjects assigned to the intervention group were contacted via weekly emails, as has been done previously, to minimize subject drop out and to confirm subject program compliance. At the end of the intervention period, subjects turned in a daily diary in which they recorded whether they were compliant (yes/no) in each category (i.e., diet, exercise, and expressions of positive thinking). Subjects were defined as dropouts and were excluded from analyses if they had an execution rate of <60% in any of the intervention categories.

The primary outcome was change in DED diagnoses and the secondary outcome was change in dry eye parameters, including dry eye symptoms, as assessed by the Dry Eye-Related Quality of Life Score questionnaire, corneal and conjunctival staining scores, tear break-up time (BUT), and Schirmer test results. General parameters (body weight, body fat percentage, body mass index, and biochemical blood tests) and the Subjective Happiness Scale score were also evaluated. These parameters were assessed at baseline and at the end of the 2-month intervention period.

### *Ethics*

This study followed the tenets of the Declaration of Helsinki, and the protocol was prospectively approved by the Seisenkai Matsumoto Clinic Institutional Review Board (Tokyo, Japan). Written informed consent was obtained from all participants. This study is registered with the University Hospital Medical Information Network (UMIN000010019).

### *Tear function tests and ocular surface evaluations*

Ophthalmic examinations were performed to determine the DED status of the participants and included assessment of conjunctival and corneal vital staining, assessment of the tear film breakup time (BUT), and measurement of tear production with a Schirmer test. Method details have been fully described in our previous study<sup>11</sup>. Briefly, the cornea and conjunctiva were assessed by fluorescein and lissamine green staining, respectively. The eye was divided into three equal compartments representing the nasal conjunctiva, cornea, and temporal conjunctiva, with a maximum staining score of three points

**Table 1.** Demographics of the 36 office worker participants.

	Intervention Group	Control Group	<i>p</i> -value
n (participants)	17	19	----
Age (years)	38.1 ± 8.4	39.3 ± 8.0	0.650
Sex (men:women)	10:7	11:8	1.000
Contact lens use (n)	10 (58.8%)	8 (42.1%)	0.505
Body weight (kg)	58.76 ± 9.89	63.71 ± 12.86	0.203
Body fat (%)	22.48 ± 4.74	25.18 ± 7.43	0.199
Body mass index	21.28 ± 2.77	22.36 ± 3.22	0.284
Physical activity (exercise)	6.6 ± 2.7	6.7 ± 3.3	0.959
Total glycemic index	754.2 ± 221.1	713.4 ± 206.6	0.603
Happiness score	0.51 ± 0.44	0.44 ± 0.42	0.616

Data are presented as mean ± standard deviation.

for each area. The overall epithelial damage was scored on a scale of 0 to 9 points (abnormal when ≥3 points). To determine the tear film BUT, the participants were requested to blink three times after instillation of fluorescein solution to ensure adequate mixing of the fluorescein dye with their tears. The time interval between the last complete blink and the appearance of the first corneal dry spot was measured using a stopwatch and the mean value of three measurements was taken as the tear film BUT (abnormal when ≤5 s). The Schirmer test was performed without topical anesthesia as the last of the three examinations (abnormal when ≤5 mm). To exclude the influence of conjunctivocorneal staining from the Schirmer test results, we conducted the test 10 min after tear film BUT assessment. All ophthalmic examinations were performed by ophthalmologists specializing in DED.

#### *Dry eye symptoms questionnaire*

The Dry Eye-Related Quality of Life Score (DEQS) questionnaire evaluates the severity of dry eye-associated symptoms. The questionnaire used in this study has been validated for use in the Japanese population and has been shown to be reliable and valid in previous studies<sup>12</sup>. The score derived from this questionnaire was considered to be a subjective measure of DED symptoms.

#### *Diagnosis of dry eye disease*

Dry eye disease was diagnosed according to the latest Japanese criteria for DED diagnosis<sup>13</sup>. Criteria included (1) the presence of dry eye symptoms, (2) the presence of qualitative or quantitative disturbance in the tear film (Schirmer test ≤ 5 mm; BUT, ≤ 5 s), and (3) the presence of conjunctivocorneal epithelial damage (total staining score ≥ 3 points). A definite DED diagnosis was given when a participant fulfilled all three criteria and a probable DED diagnosis was given when a participant fulfilled two criteria. Workers who fulfilled one or none of the three criteria were not diagnosed with DED<sup>13</sup>.

#### *Subjective Happiness Scale score*

Subjective happiness was measured using the Subjective Happiness Scale, which was developed by Lyubomirsky and Lepper in 1999<sup>14,15</sup>. The Subjective Happiness Scale is a four-item measure of global subjective happiness rated on a 7-point Likert scale<sup>15</sup>. The current study used the Japanese version of the Subjective Happiness Scale, the validity of which has already been established<sup>16</sup>. A single Subjective Happiness Scale score was computed by calculating the mean value of the individual scores for the four items. The Subjective Happiness Scale score can range from 1 to 7, with a higher score indicating a higher level of happiness.

#### *Statistical analyses*

Data from the eye with the more severe disease of the two were analyzed. Continuous data with a normal distribution are expressed as the mean±standard deviation. The baseline characteristics of the intervention and control groups were compared using unpaired *t*-tests. For the categorical variable of sex, Fisher's exact test was used. Data were compared using the paired *t*-test for continuous variables and the Wilcoxon signed rank test for keratoconjunctival epithelial damage. Workers subjectively quantified their own symptoms. The unpaired *t*-test (for continuous variables) and the Exact Wilcoxon two-sample test (for categorical variables) were used to assess the statistical significance of differences between groups. A *p*-value ≤ .05 was considered statistically significant. All statistical analyses were performed using SAS software, version 9.2 (SAS Inc., Cary, NC).

## **Results**

Of the 41 workers enrolled, 36 (intervention group, *n* = 17; control group, *n* = 19) completed this study (Supplemental Fig. 1). The characteristics of the study population are provided in Table 1. There were no significant differ-

ences between the intervention and control groups at baseline (before intervention) in physical activity, food intake, or happiness score (Table 1). At baseline, all workers were diagnosed with definite (4 workers in the intervention group, 5 workers in the control group) or probable DED (13 workers in the intervention group, 14 workers in the control group; Table 2). After 2 months, the intervention group showed a decrease in the number of DED diagnoses (the number of definite DED diagnoses decreased from four to none and the number of no DED diagnoses increased from zero to 10; Table 2, Supplemental Fig. 2) ( $p = .05$ ).

The subjective and objective findings, including the tear function test results and the vital staining scores, are shown in Table 3. At the end of 2 months, the intervention group showed a significantly lower DEQS ( $21.3 \pm 13.1$ ) than the control group ( $27.5 \pm 19.9$ ;  $p = .03$ ), although the corneal and conjunctival staining scores, tear film BUT, and Schirmer test results did not differ significantly between groups. Analysis of the scores for the items in the Ocular Symptom subscale revealed significantly lower scores for “painful or sore eyes” ( $p = .03$ ) and “ocular fatigue” ( $p = .03$ ) in the intervention group

than in the control group (Table 4). With regard to the Impact on Daily Life subscale, scores for “problems with eyes when reading” ( $p < .01$ ), “feeling distracted because of eye symptoms” ( $p < .01$ ), and “eye symptoms affect work” ( $p = .04$ ) were significantly lower in the intervention group than in the control group (Table 4). The score for the Subjective General Status subscale was also significantly higher in the intervention group.

The Subjective Happiness Scale score was significantly higher in the intervention group ( $5.75 \pm 0.64$ ) than in the control group ( $4.85 \pm 0.92$ ;  $p = .048$ ; Table 5). There were no significant differences in body weight, body fat percentage, or body mass index between the control and intervention groups after 2 months (Table 6). After the intervention, biochemical analyses (total protein, albumin, aspartate transaminase, alanine transaminase, gamma-glutamyl transpeptidase, total cholesterol, high-density lipoprotein cholesterol, triglyceride, blood urea nitrogen, creatinine, uric acid, glucose, and HbA1c) revealed no significant changes after the intervention period in either group ( $p > .05$ ).

## Discussion

This study demonstrated that 2 months of lifestyle interventions for office workers with DED resulted in a significant, subjective improvement in disease status. Short BUT-type DED is highly prevalent in office workers<sup>1)</sup> and is characterized by severe dry eye symptoms despite light ocular objective findings; it is difficult to satisfactorily treat using conventional therapies such as sodium hyaluronate eye drops<sup>17,18)</sup>. Therefore, improvement of symptoms is important, and lifestyle interventions represent a promising approach. One possible mechanism for the improvement of ocular symptoms by lifestyle interventions is dietary intake of omega-3 fatty acids, which may have increased in study participants during the study period and contributed to the improvements in dry eye status<sup>19)</sup>.

**Table 2.** Changes in dry eye disease diagnoses in office worker participants.

	Dry eye disease diagnosis	After the 2-month study period		
		At baseline	No DED	Probable DED
Intervention Group	No DED	0	0	0
	Probable DED	7	6	0
	Definite DED	3	1	0
Control Group	No DED	0	0	0
	Probable DED	4	10	0
	Definite DED	0	3	2

DED: dry eye disease.

**Table 3.** Changes in objective dry eye disease findings and subjective dry eye disease symptoms in the 36 office worker participants.

Parameters	Group	Pre	Post	$\Delta$	$p$	$p$
Vital staining score	Intervention	$1.29 \pm 1.40$	$0.88 \pm 0.93$	$-0.41 \pm 1.73$	0.4121	0.2734
	Control	$1.53 \pm 1.26$	$0.84 \pm 1.01$	$-0.68 \pm 0.89$	0.0082*	
Tear break up time (s)	Intervention	$3.22 \pm 2.71$	$3.61 \pm 2.61$	$0.39 \pm 4.04$	0.6943	0.2970
	Control	$3.28 \pm 2.7$	$4.84 \pm 2.88$	$1.56 \pm 2.15$	0.0053*	
Schirmer test results (mm)	Intervention	$7.53 \pm 8.58$	$6.06 \pm 9.15$	$-1.47 \pm 6.53$	0.3440	0.2077
	Control	$7.21 \pm 9.96$	$6.95 \pm 9.39$	$-0.26 \pm 7.02$	0.6838	
Dry Eye-Related Quality of Life Score	Intervention	$29.44 \pm 18.05$	$21.31 \pm 13.08$	$-10.42 \pm 15.47$	0.0397*	0.0318*
	Control	$26.27 \pm 17.02$	$27.5 \pm 19.94$	$1.96 \pm 12.26$	0.5192	

Data are presented as mean  $\pm$  standard deviation. \*indicates  $p < 0.05$ .  $\Delta$ : Change that occurred during the two-month study period.

**Table 4.** Changes in Dry Eye-Related Quality of Life Scores in the 36 office worker participants.

	Group	Pre		Post		Δ		<i>p</i>	<i>p</i>
		Mean ± SD		Mean ± SD		Mean ± SD			
<b>Bothersome ocular symptoms</b>									
Foreign body sensation	Intervention	1.76	1.35	1.13	1.36	-0.63	0.89	0.027*	0.096
	Control	1.33	1.03	1.50	1.04	0.17	1.25	0.560	
Dry sensation in eyes	Intervention	2.24	1.30	1.50	1.21	-0.69	1.08	0.039*	0.097
	Control	2.00	1.17	1.94	1.21	0.06	1.09	0.875	
Painful or sore eyes	Intervention	1.19	1.33	0.65	1.22	-0.50	1.97	0.289	0.039*
	Control	0.56	0.78	0.94	1.16	0.39	1.09	0.176	
Ocular fatigue	Intervention	2.76	1.39	2.00	0.82	-0.75	1.34	0.069	0.030*
	Control	2.12	0.78	2.06	0.80	0.00	0.94	1.000	
Heavy sensation in eyelids	Intervention	0.75	1.24	0.65	1.06	-0.06	1.00	0.906	0.868
	Control	0.56	0.92	0.50	0.86	-0.06	0.80	1.000	
Redness in eyes	Intervention	0.69	0.87	0.47	0.87	-0.19	1.22	0.593	0.306
	Control	0.67	1.14	0.72	1.18	0.06	0.42	1.000	
<b>Impact on Daily Life</b>									
Difficulty opening eyes	Intervention	0.82	1.29	0.53	1.18	-0.29	0.77	0.250	0.508
	Control	0.67	1.33	0.39	0.98	-0.28	1.60	0.531	
Blurred vision when watching something	Intervention	1.75	1.13	1.00	1.26	-0.73	1.53	0.119	0.082
	Control	1.61	1.46	1.67	1.19	0.06	1.11	0.984	
Sensitivity to bright light	Intervention	0.65	1.22	0.41	1.06	-0.24	0.97	0.500	0.387
	Control	0.72	1.07	0.72	1.13	0.00	0.84	0.813	
Problems with eyes when reading	Intervention	1.18	1.19	0.24	0.56	-0.94	1.25	0.012*	0.003*
	Control	0.89	1.08	1.17	1.29	0.28	1.13	0.246	
Problems with eyes when watching television or using a computer or cell phone	Intervention	1.94	1.60	1.13	1.26	-0.81	1.05	0.014*	0.066
	Control	1.71	1.21	1.61	1.33	-0.12	1.11	0.836	
Feeling distracted because of eye symptoms	Intervention	1.59	1.58	0.76	1.15	-0.82	1.13	0.016*	0.003*
	Control	1.24	1.30	1.44	1.54	0.29	0.69	0.188	
Eye symptoms affect work	Intervention	1.41	1.58	0.47	1.18	-0.94	1.64	0.039*	0.048*
	Control	1.22	1.44	1.28	1.56	0.06	1.06	1.000	
Not feeling like going out because of eye symptoms	Intervention	0.00	0.00	0.00	0.00	0.00	0.00	1.000	—
	Control	0.00	0.00	0.00	0.00	0.00	0.00	1.000	
Feeling depressed because of eye symptoms	Intervention	0.47	1.07	0.24	0.97	-0.24	1.52	0.875	0.051
	Control	0.00	0.00	0.56	1.10	0.56	1.10	0.125	
Subjective General Status	Intervention	3.82	0.64	2.94	0.66	-0.88	0.86	0.002*	0.004*
	Control	3.24	0.90	3.29	0.69	0.06	0.90	1.000	

\*indicates *p* < 0.05. SD: standard deviation.

**Table 5.** Changes in Subjective Happiness Scale scores in the 36 office worker participants.

Group	Pre	Post	Δ	<i>p</i>	<i>p</i>
Intervention Group	5.16 ± 1.20	5.75 ± 0.64	0.59 ± 0.87	0.0227*	0.048*
Control Group	5.00 ± 1.05	4.85 ± 0.92	-0.15 ± 0.81	0.5211	

\*indicates *p* < 0.05.

Lifestyle interventions, including those pertaining to physical activity and dietary behavior, were previously re-

ported to mitigate metabolic syndrome<sup>20,21</sup>. The present study shows that lifestyle interventions can also improve

**Table 6.** Changes in general condition parameters in the 36 office worker participants.

	Group	Pre	Post	$\Delta$	<i>p</i>	<i>p</i>
Body weight	Intervention	58.76 ± 9.89	58.86 ± 9.83	0.10 ± 1.67	0.808	0.164
	Control	63.71 ± 12.86	64.49 ± 12.71	0.79 ± 1.15	0.008*	
% body fat	Intervention	22.48 ± 4.74	20.46 ± 4.36	-2.01 ± 1.77	0.000*	0.830
	Control	25.18 ± 7.43	23.31 ± 7.87	-1.87 ± 2.05	0.001*	
Body mass index	Intervention	21.28 ± 2.77	21.33 ± 2.81	0.05 ± 0.58	0.727	0.158
	Control	22.36 ± 3.22	22.66 ± 3.28	0.30 ± 0.42	0.007*	

Data are presented as mean ± standard deviation. \*indicates  $p < 0.05$ .

DED. Lifestyle medicine involves the therapeutic use of lifestyle interventions to improve health and quality of life, and considers risk factors, markers, and a range of antecedent factors from all levels of causality. Treatment ultimately employs a combination of clinical (patient-centered) and public health interventions. Examples of effects on target patient behaviors include elimination of tobacco use, moderation of alcohol consumption, increase in physical activity, improvement of diet, increase in the amount of sleep, and increase in emotional and mental well-being.

In the present study, similar to the scores for ocular symptoms, scores for the items “problems with eyes when reading”, “feeling distracted because of eye symptoms”, and “eye symptoms affect work” were significantly lower in the intervention group than in the control group. It was previously reported that DED significantly impacts the total productivity of Japanese office workers<sup>22</sup>). The present study suggests that improvement of DED through lifestyle intervention results in improvements in quality of life and productivity. Lifestyle intervention may be a promising, low-cost, self-directed way to complement medical strategies for decreasing DED. In addition, anyone can implement lifestyle changes anywhere, without the need for a specific device.

However, in the present study, objective ocular parameters, including vital staining scores, tear film BUT, and Schirmer test results, did not differ significantly between the intervention and control groups, possibly because the intervention period was only 2 months. Additionally, most participants had short BUT-type DED with mild objective findings, and none were currently being treated with topical ophthalmic solutions. Combining lifestyle alterations with topical treatments would likely further improve objective and subjective findings. The long-term effects of lifestyle intervention on DED status and combination therapy with topical ophthalmic solutions remain to be investigated. Another reason for the lack of difference in objective ocular parameters could be the overall good health of study participants. We previously reported that patients with metabolic syndrome had decreased tear secretion<sup>9</sup>). Thus, more significant changes in both objective ocular findings and general bodily health

would likely be observed if patients with both DED and metabolic syndrome were included in an intervention study. In addition, lifestyle intervention ameliorates DED and improves the general condition of the body, which is useful for improving metabolic syndrome. The incidence of DED and metabolic syndrome as modern diseases has increased and will likely continue to increase in the future, necessitating increased lifestyle intervention programs.

The Subjective Happiness Scale score increased significantly in the intervention group compared with the control group. We previously reported that individuals with a low Subjective Happiness Scale score exhibited severe dry eye symptoms<sup>10</sup>). In the present study, we showed that lifestyle intervention increased the Subjective Happiness Scale score in addition to decreasing DED symptoms. We propose that DED symptoms are related to mental health problems, and that lifestyle intervention has the potential to ameliorate these symptoms. Several studies have reported that DED is related to depression<sup>23-25</sup>), and lifestyle interventions, such as exercise, have been shown to be therapeutic for depression<sup>26</sup>). Further studies should focus on mental health problems in DED patients. Unfortunately, subjects were not followed after the intervention period, so we cannot know whether lifestyle changes continued beyond the study. Seligman et al.<sup>27</sup>) previously reported that some of the happiness interventions used here can have a lasting effect of increasing happiness and decreasing depression symptoms. Future studies should have a follow-up period that extends beyond the intervention period; however, we can conclude that positive interventions can supplement traditional interventions to relieve suffering from dry eye symptoms.

Subjects randomized to the control group were instructed to continue living their life as usual. Subjects randomized to the intervention group were sent weekly e-mails to minimize patient drop out, as was done previously by others. Because weekly emails were only sent to subjects in the intervention group, the intervention group may have inadvertently been encouraged to live a healthier life. However, because baseline data, which was collected 1 week before study group assignment, did not show statistical differences between the groups in food in-

take, exercise habits, or subjective happiness, we expect that our emails had little influence on the lifestyle of the intervention group. However, this point should be considered in future studies. Another limitation was the inability to mask group assignments: i.e., the subjects in the intervention group were aware of and understood the intervention being applied, and thus expected that the intervention would produce positive effects on their dry eye condition. In other words, the Hawthorne effect cannot be ruled out. Unfortunately, our subjects were not followed after the intervention period, so we cannot know whether the symptoms worsened after the intervention was discontinued. This point should be considered in future studies.

In conclusion, lifestyle interventions may be a promising DED management option. Further investigations to clarify the long-term effects of lifestyle changes are required.

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*Supplementary material:* This article contains supplementary material (Appendix), which is available in the online version (doi: 10.1539/joh.2017-0191-OA)

## References

- 1) Uchino M, Yokoi N, Uchino Y, et al. Prevalence of dry eye disease and its risk factors in visual display terminal users: the Osaka Study. *American Journal of Ophthalmology* 2013; 156(4): 759-766.
- 2) Uchino M, Schaumberg DA, Dogru M, et al. Prevalence of dry eye disease among Japanese visual display terminal users. *Ophthalmology* 2008; 115(11): 1982-1988.
- 3) The epidemiology of dry eye disease: report of the Epidemiology Subcommittee of the International Dry Eye WorkShop (2007). *Ocular Surface* 2007; 5(2): 93-107.
- 4) Collins M, Brown B, Bowman K, et al. Workstation variables and visual discomfort associated with VDTs. *Applied Ergonomics* 1990; 21(2): 157-161.
- 5) Thomson WD. Eye problems and visual display terminals--the facts and the fallacies. *Ophthalmic & Physiological Optics* 1998; 18(2): 111-119.
- 6) Miljanović B, Dana R, Sullivan DA, et al. Impact of dry eye syndrome on vision-related quality of life. *American Journal of Ophthalmology* 2007; 143(3): 409-415.
- 7) Mizuno Y, Yamada M, Miyake Y; Dry Eye Survey Group of the National Hospital Organization of Japan. Association between clinical diagnostic tests and health-related quality of life surveys in patients with dry eye syndrome. *Japanese Journal of Ophthalmology* 2010; 54(4): 259-265.
- 8) Kawashima M, Uchino M, Yokoi N, et al. The association between dry eye disease and physical activity as well as sedentary behavior: results from the Osaka Study. *Journal of Ophthalmology* 2014; 2014: 943786.
- 9) Kawashima M, Uchino M, Yokoi N, et al. Decreased tear volume in patients with metabolic syndrome: the Osaka Study. *British Journal of Ophthalmology* 2014; 98(3): 418-420.
- 10) Kawashima M, Uchino M, Yokoi N, et al. Associations between subjective happiness and dry eye disease: a new perspective from the Osaka Study. *PLoS One* 2015; 10(4): e0123299.
- 11) Sano K, Kawashima M, Ito A, et al. Aerobic exercise increases tear secretion in type 2 diabetic mice. *Investigative Ophthalmology and Visual Science* 2014; 55(7): 4287-4294.
- 12) Sakane Y, Yamaguchi M, Yokoi N, et al. Development and validation of the Dry Eye-Related Quality-of-Life Score questionnaire. *JAMA Ophthalmology* 2013; 131(10): 1331-1338.
- 13) Shimazaki J, Tsubota K, Kinoshita S. Definition and diagnosis of dry eye. *Atarashii Ganka* 2007; 24: 181-184.
- 14) Mattei D, Schaefer CE. An investigation of validity of the subjective happiness scale. *Psychological Reports* 2004; 94(1): 288-290.
- 15) Lyubomirsky S, Lepper HS. A measure of subjective happiness: preliminary reliability and construct validation. *Social Indicators Research* 1999; 46: 137-155.
- 16) Shimai S, Otake K, Utsuki N, et al. [Development of a Japanese version of the Subjective Happiness Scale (SHS), and examination of its validity and reliability]. [*Nihon Kosho Eisei Zasshi*] *Japanese Journal of Public Health* 2004; 51(10): 845-853.
- 17) Yokoi N, Uchino M, Uchino Y, et al. Importance of tear film instability in dry eye disease in office workers using visual display terminals: the Osaka Study. *American Journal of Ophthalmology* 2015; 159(4): 748-754.
- 18) Kaido M, Uchino M, Kojima T, et al. Effects of diquafosol tetrasodium administration on visual function in short break-up time dry eye. *Journal of Ocular Pharmacology and Therapeutics* 2013; 29(6): 595-603.
- 19) Bhargava R, Kumar P, Phogat H, et al. Oral omega-3 fatty acids treatment in computer vision syndrome related dry eye. *Contact Lens Anterior Eye* 2015; 38(3): 206-210.
- 20) Matsuzawa Y, Sugiyama S, Sugamura K, et al. Successful diet and exercise therapy as evaluated on self-assessment score significantly improves endothelial function in metabolic syndrome patients. *Circulation Journal* 2013; 77(11): 2807-2815.
- 21) Loprinzi PD, Smit E, Mahoney S. Physical activity and dietary behavior in US adults and their combined influence on health. *Mayo Clinic Proceedings* 2014; 89(2): 190-198.
- 22) Uchino M, Uchino Y, Dogru M, et al. Dry eye disease and work productivity loss in visual display users: the Osaka Study. *American Journal of Ophthalmology* 2014; 157(2): 294-300.
- 23) Kim KW, Han SB, Han ER, et al. Association between depression and dry eye disease in an elderly population. *Investigative Ophthalmology and Visual Science* 2011; 52(11): 7954-7958.
- 24) van der Vaart R, Weaver MA, Lefebvre C, et al. The associa-

- tion between dry eye disease and depression and anxiety in a large population-based study. *Am J Ophthalmol* 2015; 159(3): 470-474.
- 25) Labbé A, Wang YX, Jie Y, et al. Dry eye disease, dry eye symptoms and depression: the Beijing Eye Study. *British Journal of Ophthalmology* 2013; 97(11): 1399-1403.
- 26) Cooney GM, Dwan K, Greig CA, et al. Exercise for depression. *The Cochrane Database of Systematic Reviews* 2013; (9): CD004366.
- 27) Seligman MEP, Steen TA, Park N, et al. Positive psychology progress: empirical validation of interventions. *American Psychologist* 2005; 60(5): 410-421.