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.

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. 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.

Dry eye disease can be debilitating because it can impair visual function and cause difficulty in tasks requiring sustained visual concentration. 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. 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. For instance, decreased physical activity and sedentary behavior are associated with DED, and metabolic syndrome is associated with decreased tear secretion. Furthermore, decreased subjective happiness is reportedly associated with severe dry eye symptoms. We recently reported that aerobic exer-
cise increases tear secretion in mice with type 2 diabetes\textsuperscript{19}. 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.

During the week prior to subject group assignment, workers 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\textsuperscript{11}. 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 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.
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 fluorescein dye with their tears was measured using a stopwatch and the mean last complete blink (BUT) was computed by calculating the mean value of the individual results. A single Subjective Happiness Scale score was assessed using the Japanese version of the Subjective Happiness Scale, which was developed by Lyubomirsky and Lepper in 1999. The Subjective Happiness Scale is a four-item measure of global subjective happiness rated on a 7-point Likert scale. The current study used the Japanese version of the Subjective Happiness Scale, the validity of which has already been established. 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.

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

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

Data are presented as mean ± standard deviation.

**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±13.1) than the control group (27.5±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±0.64) than in the control group (4.85±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 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. 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.

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

<table>
<thead>
<tr>
<th>Dry eye disease diagnosis</th>
<th>At baseline</th>
<th>No DED</th>
<th>Probable DED</th>
<th>Definite DED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intervention Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No DED</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Probable DED</td>
<td>7</td>
<td>6</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Definite DED</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Control Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No DED</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Probable DED</td>
<td>4</td>
<td>10</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Definite DED</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

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.

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

Data are presented as mean ± standard deviation. *indicates $p < 0.05$. $\Delta$: Change that occurred during the two-month study period.
Lifestyle interventions, including those pertaining to physical activity and dietary behavior, were previously reported to mitigate metabolic syndrome\textsuperscript{20,21}. The present study shows that lifestyle interventions can also improve...
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. 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. 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. 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, and lifestyle interventions, such as exercise, have been shown to be therapeutic for depression. 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. 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 emails 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.

Conflicts of interest: Provision of facilities and the transportation of equipment were supported by Santen Pharmaceutical Co., Ltd. (Osaka, Japan). The sponsors had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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

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24) van der Vaart R, Weaver MA, Lefebvre C, et al. The associa-

