Exposure to a Controlled Adverse Environment Impairs the Ocular Surface of Subjects with Minimally Symptomatic Dry Eye

Maria J. González-García,1 Arancha González-Sáiz,1 Beatriz de la Fuente,2 Antonio Morilla-Grasa,1 Agustín Mayo-Iscar,3 Julio San-José,2 Jesus Feijó,2 Michael E. Stern,4 and Margarita Calonge1

PURPOSE. Adverse environmental conditions elicit dry eye (DE)-related signs and symptoms. The purpose of this work is to determine whether these conditions can alter a normal-to-borderline ocular surface in subjects with DE symptoms.

METHODS. Ten minimally symptomatic contact lens (CL)-wearing subjects were exposed, without (WO-) and with (W-)CLs, to a controlled adverse environment (CAE) of 22.0 ± 2.0°C and 19.0% ± 4.0% relative humidity (RH) for 2 hours in an environmental chamber (EC). One month later, the same subjects were placed in an indoor normal environment (INE) of 24.2 ± 1.3°C and 34.8% ± 2.9% RH for 2 hours. DE-related signs and symptoms were evaluated before and after each exposure. The reversibility of changes provoked by CAE or INE was also evaluated.

RESULTS. Without CL wear, significant changes were found in DE signs (noninvasive tear break-up time [NIBUT], conjunctival hyperemia and phenol red thread test) after CAE exposure, but not found after INE exposure. However with CL wear, the same tests were altered after both CAE and INE exposure. Most of these changes returned to normal values within 1 month after environmental exposure.

CONCLUSIONS. Significant changes in comfort and the ocular surface tests were found after 2 hours of exposure to CAE. These results show the negative impact that an adverse environment, especially low RH, can have on the ocular surface. These alterations were fully reversible. This indicates that the CAE is a safe and functional condition in which to standardize DE diagnostic tests and evaluate therapeutics.

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From the 1Ocular Surface Group, Institute of Applied Ophthalmology (IOBA), the 2School of Architecture, and the 3Department of Statistics and Operative Research, University of Valladolid, Valladolid, Spain; and the 4Division of Biological Sciences, Allergan, Inc., Irvine, California.


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Corresponding author: María J. González-García, IOBA/University of Valladolid, Ramón y Cajal 7, Valladolid E-47005, Spain; aluch@ioba.med.uva.es.

Adverse environmental conditions such as excessive heat, wind, or low humidity elicit dry eye (DE)-related signs and symptoms.1,2 These environments exist throughout the world, especially in those regions with arid or semiarid climates and warm weather. Moreover, millions of individuals are exposed to these conditions in artificially controlled environments such as air-conditioned or artificially heated rooms, vehicles, and airplane cabins. These conditions can affect the occupants and interfere with daily living and working activities and have given rise to the descriptive term sick-building syndrome.3,4 In addition, reading or computer use can further worsen those situations.5,6

To understand the way that environment affects the ocular surface and provokes signs and symptoms of DE, it is necessary to control exposure conditions such as humidity, temperature, air flow, and pollutants. Environmental chambers (ECs) have been used to create controlled environments to evaluate subject responses to a determined stimulus. An example is the assessment of antiallergic drug effectiveness in subjects exposed to a controlled allergen charge.7–9 Studies that show the influence on the ocular surface of irritating factors such as cigarette smoke,10 dust,11 or topically instilled topical drugs12 have also been performed in ECs.

Controlled adverse environments (CAEs) created with ECs have been used to develop animal models of DE.13,14 CAEs can improve the design of clinical trials and have been used to study the effects of DE therapeutics1,15,16 and to evaluate the effect of contact lens (CL) wear on the ocular surface.16,17

The purpose of this study was threefold. First, we determined whether a CAE adversely affects the normal-to-borderline ocular surface of young, healthy persons with symptoms induced by CL wear. Second, we evaluated the possible negative impact of CL wear in a CAE. Third, we determined whether the alterations of the ocular surface were reversed after cessation of adverse environment exposure. The results from the CAE were then compared to results of similar exposure of the same subjects to an indoor normal environment (INE).

MATERIALS AND METHODS

Subject Enrollment

Because individuals having only mild and occasional DE-related symptoms were the subjects of this study, we elected to enroll only young and healthy individuals who had developed minimal DE-related signs and/or symptoms as a consequence of CL use, and who were symptomatic only when the CLs were in place. Ten young individuals with myopia were enrolled in the study. The criteria for selecting well-qualified subjects and rejecting others ensured that the subjects were healthy, experienced CL wearers, with minimal symptoms of DE that occurred only while wearing CLs. In addition, the subjects must have had results within normal limits in at least three of the following five DE tests: tear film breakup time (T-BUT), >10 seconds49, negative
fluorescein corneal staining\textsuperscript{27}, negative rose bengal conjunctival staining\textsuperscript{20}, Schirmer test with anesthesia, \(>5\) mm in 5 minutes\textsuperscript{21}; and tear lysozyme concentration, \(>1000\) µg/mL\textsuperscript{22,23}

The nature of the research and protocols was explained to the subjects before written informed consent was obtained during the screening visit. The study complied with the tenets of the Declaration of Helsinki, and the protocol was approved by the Institutional Review Board of the University of Valladolid.

### Environmental Conditions

Subjects were exposed to two different environmental conditions that differed principally in relative humidity (RH).

**Controlled Adverse Environment.** Individuals were subjected to a controlled adverse environment (CAE) in an EC located in the Environmental Laboratory (School of Architecture, University of Valladolid). The EC is an isolated room 4.6 m wide, 5.8 m deep, and 2.5 m high. Two of the walls and the roof of the EC are made of plaster board. The other two walls are made of double-paned windows, to facilitate observing the interior of the chamber from the outside. The floor is made of wood covered with linoleum. The EC was equipped with a closed air circulation system consisting of a circular duct with propellant and return vents. Temperature and RH could be precisely controlled between 20°C and 30°C and RH from 15% to 80%, with a 10% tolerance. For temperature control, the EC air conditioning system (SDH 105, TD Saunier-Duval; Valliant, Remscheid, Germany) had a cooling capacity of 10.20 kW and a heating capacity of 11.6 kW. The RH was reduced by using the indoor coil of the air conditioning system to condense the water vapor in the air. A more stable control of RH was achieved with a 1.13-kW and 1.5-kg/h humidifier (Humisteam UE001PD000; Carel, Padova, Italy). Control the EC conditions was facilitated observing the interior of the chamber from the outside. The board. The other two walls are made of double-paned windows, to

**Indoor Normal Environment.** Four weeks after exposure to a CAE, individuals were subjected to an indoor normal environment (INE). This real-life environment was located in a room in one of the University libraries. For 2 hours, the subjects did the same kind of reading activity as during the CAE exposure. The temperature and RH were measured at two different places inside the room with a weather station (EMBR12GHN; Oregon Scientific, Tualatin, OR) at 9 AM, 1 PM, and 6 PM. The mean temperature and RH were 24.2°C ± 1.3°C and 34.8% ± 2.9%, respectively. As the whole experiment was held during winter, the environment in the library was artificially heated and had no air flow.

### Tests Performed

The following examinations were performed in the following sequence and as outlined in Table 1.

**DE-Related Symptomatology.** Comfort was rated on a scale of 0 to 10 by subjects answering a 100-mm vertical visual analogue scale\textsuperscript{24,25} on which 0 indicated extreme discomfort and 10 extreme comfort. For evaluation of DE-related symptoms, the symptoms of discomfort questionnaire (SODQ) was answered by each individual. Symptoms such as dryness, a sandy or gritty feeling, burning or stinging, pain, itching, sensitivity to light, and blurred vision were graded on a scale of 0 to 4. The total score was derived from the addition of partial scores of each symptom.

**Noninvasive Tear Break-Up Time.** A device for assessing tear film (Tearscope Plus; Keeler, Windsor, UK) was used to measure the Schirmer test with anesthesia, \(>5\) mm in 5 minutes; tear lysozyme concentration, \(>1000\) µg/mL; and tear film (Tearscope Plus; Keeler, Windsor, UK) was used to measure the mean of three measurements was recorded.\textsuperscript{26} Values of 10 seconds or less were considered abnormal.\textsuperscript{27}

**Bulbar and Limbal Conjunctival Hyperemia.** Bulbar conjunctival and limbal hyperemia were evaluated with a slit lamp (SL-BZ; Topcon Corp., Tokyo, Japan) on a 0.1 decimalized scale (range, 0–4).\textsuperscript{19} Redness of 2.6 or greater was considered abnormal.\textsuperscript{28}

**Phenol Red Thread Test.** The phenol red thread test (Zone Quick Test; Menicon Ca, Ltd., Nagoya, Japan) was placed in the recommended position over the lateral canthus and read 15 seconds after placement.\textsuperscript{29} Values of 20 mm or below were considered abnormal.\textsuperscript{30}

**Tear Break-up Time.** For tear break-up time (T-BUT) measurements, fluorescein strips previously wetted with 0.9% sodium chloride (NaCl 0.9% 10 mL; B/Braun, Barcelona, Spain) were gently applied to the inferior fornix. T-BUT was measured after three blinks, and the mean of three measurements was recorded.\textsuperscript{31} Values of 10 seconds or below were considered abnormal.\textsuperscript{32}

**Corneal and Conjunctival Vital Staining.** Corneal fluorescein staining was evaluated with fluorescein strips (Fluores; Chauvin, Aubenas, France). After they were wetted with 0.9% sodium chloride, they were gently applied to the inferior fornix. The cornea was divided into five regions (central, superior, inferior, nasal, and temporal), and

#### Table 1. Protocol of Visits and Tests

<table>
<thead>
<tr>
<th>Visit</th>
<th>Evaluation</th>
<th>Evaluation Description</th>
<th>DE-Related Symptoms</th>
<th>Conjunctival Hyperemia</th>
<th>Phenol Red Thread Test</th>
<th>Fluorescein Staining</th>
<th>Tear Lysozyme</th>
<th>Schirmer Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1</td>
<td>E1</td>
<td>Pre-CAE WO-CL</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>E2</td>
<td></td>
<td>Post-CAE WO-CL</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>V2</td>
<td>E3</td>
<td>Pre-CL wear</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>E4</td>
<td></td>
<td>Pre-CAE W-CL</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>E5</td>
<td></td>
<td>Post-CAE W-CL</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>V3</td>
<td>E6</td>
<td>Pre-INE WO-CL</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>E7</td>
<td></td>
<td>Post-INE W-CL</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>V4</td>
<td>E8</td>
<td>Pre-CL wear</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>E9</td>
<td></td>
<td>Pre-INE W-CL</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>E10</td>
<td></td>
<td>Post-INE W-CL</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

CAE (22 ± 2°C, RH 19% ± 4%); INE (24.2 ± 1.3°C, RH 34.8% ± 2.9%).
each region was graded on a 0.1 decimalized scale (range, 0–4).

The sample size was established to detect differences below 2 seconds (over baseline conditions) in NIBUT and 3 mm in the Schirmer test. Toward this goal, information about variability of these tests, along with a hypothesis relative to the estimated gain in power due to the paired nature of this study design was used.

Statistical Analysis

Results are expressed as the mean ± SEM. The geometric mean was added for those variables in which log-transform was used (NIBUT and tear lysozyme concentration) with the intention of gaining interpretability by recovering the usual scale. The geometric mean was reoriented as $e^{\bar{y}} \pm \text{SEM}$. When a test was performed in both eyes, the mean of the two measurements was used in the statistical analysis.

Among the available methods to analyze data, with some ordinal measures, the ones in the parametric family were chosen, due to the belief that all the variables measured in this study (in case of NIBUT and tear lysozyme concentration after log transform) supports the hypothesis: for three values $x$, $y$, and $z$, the change in magnitude between $x$ and $x + z$ is clinically comparable to the difference between $y$ and $y + z$.

Assuming this hypothesis being true, it makes sense to add data from different subjects, and in this situation, a high-efficiency summary for the location of the observed values in the sample is the mean, and the SEM can be used as a measure of the estimated error.

The use of this methodology necessarily assumes that the above mentioned hypothesis is true. In addition, parametric procedures for comparison of the means are quite robust with normality deviations, except when they are due to heavy tailed which is not the present case.

In the framework of a repeated-measures analysis, a multiple-comparison method based on Tukey’s theory was applied, to test the difference between evaluations (E1–E10). The Mauchly test and epsilon estimate were performed to verify the sphericity condition. NIBUT and the tear lysozyme concentration met this condition after a logarithmic transformation was performed. For variables that appeared with evidence of a sphericity hypothesis violation, a separate variance estimation in a multiple-comparison procedure was used.

$P \leq 0.05$ was considered to show statistical significance.

RESULTS

Screening Visit (V0)

Three men and seven women with a mean age of 25.2 ± 0.9 years (range, 22–34) were recruited. Mean myopia of the group was $-3.6 \pm 0.2$ D (range, $-1.50$ to $-5.75$). They had worn their CLs for a mean of $4.9 \pm 0.5$ years (range, 3–8) and had a wearing schedule of $8.6 \pm 0.5$ h/d (range, 6–12). Screening evaluation results were within the inclusion criteria (SODQ: $0.76 \pm 0.09$; T-BUT: $10.1 \pm 1.0$; corneal fluorescein staining: $0.1 \pm 0.05$; rose bengal staining: $0.2 \pm 0.08$; tear lysozyme concentration: $7.88$ (2657.71) µg/mL; Schirmer test with anesthesia: $13.5 \pm 1.8$ mm). All subjects were asymptomatic while not wearing CLs, and dryness was reported by all subjects only while wearing CLs, in accordance with the inclusion criterion.

Environmental Exposure–Induced Changes

Initial baseline values (E1, E3, E6, and E8) of all variables were within the clinically normal range. To evaluate the influence of exposure to the CAE or the INE, means of the variables evaluated before exposure (E1, E3, E6, and E8) and after exposure (E2, E5, E7, and E10) were compared (Table 2).

When subjects were inside the CAE, their comfort was evaluated at 1 and 2 hours (Fig. 1, Table 2). For CAE exposure without CL, there were no significant changes after 1 or 2 hours. However, when CLs were in place, there was a constant
TABLE 2. Results of the Different Visits

<table>
<thead>
<tr>
<th>Visit</th>
<th>Comfort</th>
<th>SOQD</th>
<th>NIBUT</th>
<th>Schirmer Test</th>
<th>Tear Lysozyme Concentration</th>
<th>Phenol Red Thread Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>V0 (Screening)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>E1</td>
<td>1.8 ± 0.4</td>
<td>—</td>
<td>1.9 ± 0.6</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>E2</td>
<td>1.9 ± 0.6</td>
<td>—</td>
<td>1.8 ± 0.7</td>
<td>—</td>
<td>1.0 ± 0.0</td>
<td>2.11 ± 2.4</td>
</tr>
<tr>
<td>E3</td>
<td>1.8 ± 0.7</td>
<td>—</td>
<td>1.9 ± 0.9</td>
<td>—</td>
<td>1.6 ± 0.00</td>
<td>2.60 ± 1.5</td>
</tr>
<tr>
<td>E4</td>
<td>1.9 ± 0.9</td>
<td>—</td>
<td>1.9 ± 1.1</td>
<td>—</td>
<td>1.5 ± 0.00</td>
<td>1.0 ± 0.7</td>
</tr>
<tr>
<td>E5</td>
<td>1.5 ± 0.00</td>
<td>—</td>
<td>1.5 ± 0.05</td>
<td>—</td>
<td>1.4 ± 0.00</td>
<td>2.31 ± 2.6</td>
</tr>
<tr>
<td>E6</td>
<td>1.4 ± 0.00</td>
<td>—</td>
<td>1.5 ± 0.05</td>
<td>—</td>
<td>1.3 ± 0.00</td>
<td>1.3 ± 0.00</td>
</tr>
<tr>
<td>E7</td>
<td>1.3 ± 0.00</td>
<td>—</td>
<td>1.3 ± 0.05</td>
<td>—</td>
<td>1.3 ± 0.00</td>
<td>1.0 ± 0.00</td>
</tr>
<tr>
<td>V4 (INE W-CL)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

All data are expressed as the mean ± SEM, except for NIBUT and tear lysozyme concentration, which are expressed as the geometric means and the concentrations, respectively.

FIGURE 1. Changes in comfort during 2 hours of CAE exposure. *P < 0.05 between 0 and 1 hour with CL. †P < 0.05 between 1 and 2 hours with CL.

Effect of Wearing CLs

To evaluate the effect of CL wear in CAE and INE conditions, the comfort of pre- and postevaluations without CL (CAE E2-E1 and INE E7-E6) were compared with differences between pre- and postvisits with CLs (CAE E5-E4 and INE E10-E9). NIBUT demonstrated a higher decrease without than with CLs in the CAE (difference not found in the INE), and the phenol red thread test showed a higher decrease with CLs than without them, in both CAE and INE situations (Table 2).

Short- and Long-Term Recovery

The reversibility of changes provoked by CAE or INE exposure was studied, to evaluate the safety of the environmental conditions. To do this, a short-term recovery was defined as the absence of significant changes 4 to 7 days after CAE exposure between E1 and E3 (CAE WO-CL) or after INE exposure between E6 and E8 (INE WO-CL). For CAE, long-term recovery (5 weeks) was defined as the absence of changes between E1 and E6 (CAE WO-CL) or E4 and E9 (CAE W-CL).
The short-term recovery analysis for CAE conditions without CLs (E1, E3; Table 2) showed that symptoms improved 4 to 7 days after exposure, and for INE conditions without CLs, limbal hyperemia significantly improved (E6, E8; Table 2). The long-term recovery analysis after CAE exposure also showed that ocular surface had almost completely returned to the previous values. Thus, 30 days after going through CAE, either with or without CL, values were similar or even better than at the outset. NIBUT and limbal hyperemia with CL improved significantly (E4, E9; Table 2).

**DISCUSSION**

The purpose of this study was to determine whether the RH differences between the CAE (20% RH) and INE (35% RH) could affect the ocular surface health of CL wearers who had minimal symptoms of DE. We demonstrated that a normal-to-borderline ocular surface can be negatively affected by CAE conditions lasting for as short as 2 hours, and that CL can induce similar changes on the ocular surface, even in INE conditions. The reversibility of the altered characteristics indicated that, at least in these conditions, no disease was induced in these subjects.

In this study, we evaluated the influence that variations in RH can have on the ocular surface of humans, maintaining nearly constant the other variables that can influence the results such as temperature, air flow, and visual tasks. Though the relationship is not exactly linear, RH levels vary inversely with temperature when water vapor remains constant. We analyzed the influence of 19.0% RH in the CAE and 34.8 RH in the INE on the ocular surface while maintaining similar temperature, 22.0°C for the CAE and 24.2°C for the INE. Thus, findings are mainly attributed to the differences in RH.

Morgan et al. found no changes in the dehydration of CL or comfort in subjects exposed to different RH and temperature levels. However, they used low levels of RH in conjunction with high temperatures (5% RH at 30°C) and high RH with low temperatures (90% RH at 5°C). Thus, their conditions were not comparable to ours. Maruyama et al. used low RH at low temperatures (90% RH at 5°C). When the two variables were changed simultaneously, the effects of RH changes alone were unclear. Nevertheless, the changes they found in NIBUTs, interference patterns, and dryness symptoms support our findings that low RH increases DE signs and symptoms.

The subjective responses of individuals were evaluated with the comfort-based visual analog scale and the symptoms-based SODQ so as to avoid missing symptoms due to the difference in the way individuals express themselves. The results obtained in comfort and symptoms scores differed from one another. While comfort was decreased in the CAE with CLs, there were no changes in symptoms. These results can be explained in two ways. First, both tests evaluated different parts of the subjective response, as subjects may interpret words as “comfort” or “dryness” as different sensations. Second, comfort and symptoms were measured in different ways. Comfort was assessed with a 0-to-10 visual analog scale that was more sensitive than the 0-to-4 verbal scale used to assess symptoms.

The fact that there was no significant decrease in comfort after 2 hours of CAE exposure without CLs could indicate that further studies with these conditions should be longer. However, comfort with CLs decreased during the first hour, indicating that this variable is more affected by CL wear; therefore, we conclude that studies with CLs could be of shorter duration.

NIBUT was performed to assess tear film stability instead of T-BUT used in the screening visit because it permitted us to evaluate tear film behavior on the surface of the CLs. Without CLs, tear film stability was negatively affected after 2 hours of CAE exposure, in agreement with other authors. Maruyama et al. observed no changes in NIBUT without CLs when subjects were exposed to CAE for 15 minutes. This short exposure probably explains the difference between their results and ours. In our study, NIBUT was not influenced when CLs were on. Thus, the CL may protect the ocular surface from external changes for a short period. Nilsson and Andersson observed a decrease in T-BUT in CL wearers when RH was below 31% in working places and exposure times were longer than 2 hours. However, Maruyama et al. found a decrease in NIBUT when subjects were exposed to low RH when wearing CLs. More work is needed to clarify this discrepancy.

Both limbal hyperemia and conjunctival fluorescein staining increased secondary to exposure to the CAE without CLs, indicating that the ocular surface was altered during the adverse conditions. With CL wear, both the CAE and the INE induced conjunctival hyperemia. Increases in limbal redness has also been found by other investigators, and it has been attributed to the local hypoxia that can be induced on the limbal conjunctiva by the edge of the CLs.

Although the Schirmer and tear lysozyme concentration tests are good to evaluate tear production, we did not find any variation with CAE or INE exposure. Possibly the exposure time was too short to show any change in normal-to-borderline subjects; however, there are inconsistent results in the literature related to Schirmer variations in adverse environments. Paschides et al. found a decrease in Schirmer results in subjects living in cities with dry climates; however Muzi et al. did not find any difference in subjects working in so-called sick buildings, defined as air-conditioned buildings in which employees had a high prevalence of irritative symptoms involving the eye and respiratory tract compared with that of subjects working in so-called healthy buildings. Another reason for our findings is that we studied nearly normal subjects. DE subjects can be more affected by CAE, as others have found. The phenol red thread test was the only measure of production that changed after environmental exposure. It decreased in the CAE without CLs, but not in the INE, perhaps because the phenol red thread test is less invasive and detected more subtle changes than did the Schirmer test or tear lysozyme concentration tests. With CL wear, the phenol red thread test decreased in the INE, indicating that the presence of CL in some way alters tear production in a similar way that CAE does.

In general, we found that the CAE affects more negatively a normal-to-borderline ocular surface than the INE. McCulley et al. found that a decrease in RH results in an increase in tear evaporation. The low RH to which subjects were exposed during CAE in our study could have provoked an increase in tear evaporation that led to the changes in signs and symptoms that we observed. Although this possibility seems likely in our experimental conditions, we did not actually measure tear evaporation.

CAE conditions seemed to affect the ocular surface more negatively when no CLs were worn compared with INE conditions in which no change in any variable occurred. These results can be explained by the fact that individuals selected for this study were symptomatic only when CLs were used. This finding means that the presence of a CL produces changes in the ocular surface that provoke those variations, even in normal situations, because the CL itself increases tear evaporation, masking the effect that 2 hours of exposure to CAE could have had on the ocular surface.

The modest change found in some studied variables (i.e., bulbar and limbal hyperemia) although statistically significant, seems to be of little clinical relevance. However, the small differences in humidity between CAE (22 ± 2°C, RH 19% ±...
and to evaluate new diagnostic technologies or therapies.1

Recently, adverse environments with high rates of air flow have been used to create three models of keratoconjunctivitis sicca in mice: transdermal scopolamine patches,13 controlled low RH,14 and low RH with abnormally low-blink frequency.52

The desiccating stresses induce inflammatory responses that are implicated in the pathogenesis of DE disease.53,54 These animal models can be replicated in humans in a CAE and an EC. Because low RH provokes an increase in tear evaporation that leads to hyperosmolarity of tears,55 it may be one of the causative factors of inflammation in DE disease.56

Our CAE and INE models will permit improvement in the design of clinical trials. DE is one of the most common ocular problems in the general population,57 but there is a lack of international consensus on diagnosis criteria or clinical test end points.58 The standardization of CAE and EC conditions will help to produce repeatable outcomes in both clinical and research applications. It will also help to define test end points and to evaluate new diagnostic technologies or therapies.5

In conclusion, the present study demonstrated that adverse environmental conditions can alter a normal-to-borderline ocular surface status. The wearing of CLs has a similar impact on the ocular surface in the CAE as in the INE, and alterations induced by these environments are reversed after 1 week. Therefore, the conditions recreated in this study can be of further use to standardize ocular surface status in the evaluation of DE diagnostic end points and/or to test new therapies.

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References


