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Impact of Air Movement on Eye Symptoms

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Abstract

The impact of direction, oscillation and temperature of isothermal room air movement on eye discomfort and tear film quality was studied. Twenty-four male subjects participated in the experiment. Horizontal air movement against the face and chest was generated by a large desk fan – LDF and a small desk fan (2.5 W) powered by laptop computer – USBF and upward movement by a personalized ventilation supplying air from desk front edge - PV. The exposed subject had control over the rotation speed of the fans as well as the personalized airflow rate and its direction to be against the chest, upward to the face or both. At room air temperature of 25 °C and relative humidity of 50 % the subjects were exposed for 30 min to three conditions - without elevated air movement and USBF with and without oscillation and to six conditions at 30 °C and 50 % RH – without elevated movement, USBF without oscillation when the airflow was directed against the face and when against the chest, LDF with and without oscillation and PV. Eye tear film samples were taken and analyzed at the beginning and the end of the exposures. Eye irritation and dryness were reported by the subjects. The air movement under individual control did not change significantly the tear film quality though tendency for improvement was observed. Eye dryness increased much when the airflow was blowing constantly against the face compared to oscillating airflow, airflow directed against the chest and upward airflow against the face.

Keywords – air movement direction; air temperature; eye tear film quality; eye irritation; eye dryness

1. Introduction

Recently, the use of elevated air movement and maintaining indoor temperature above the upper level of comfortable temperature has been recommended as an energy saving strategy during summer or at warm climates. The standards recommend air movement locally applied at each workstation and under individual control of the occupant [1, 2]. Cooling fans (desk, ceiling, and other type) or personalized ventilation (PV) are some of the means to generate elevated air movement in enclosed spaces. Cooling fans generate movement of room air, i.e. polluted and warm (may also be humid) air. In the case of PV air is typically supplied cooler and cleaner (and in some cases dryer) than the room air [3]. It has been documented that at warm environment facially applied air movement (even of polluted room air) with elevated velocity improves acceptability of perceived air quality (PAQ) and air freshness as well as thermal comfort [4]. It has also been reported that air movement of polluted room air does not decrease the intensity of SBS symptoms while a flow of clean, cool and dry air as supplied by personalized ventilation does [4, 5].

The purpose of normal eye blinking is to restore the tear film and to defend the eye from environmental exposure. An increase in air temperature and relative humidity decreases the evaporation of the tear film and thus the blink rate [6, 7]. The increase of air velocity increases the tear film evaporation resulting in increase of the blink rate [6]. However it has been also reported that facially applied air movement does not affect eye blink frequency when it is under individual control [7, 8]. It was found that break-up time of the pre-corneal film after a blink significantly decreased at exposure to air movement at 1.0 m/s but not to 0.5 m/s [9]. A negative impact of increased air temperature and relative humidity on eye tear film quality was reported but not of increased air movement when under individual control of the exposed person [10]. Studies [7, 11] reported that air movement significantly increased the perception of eye dryness.

It is well known that at unchanged other conditions an increase of turbulence intensity enhances heat exchange. An increase of air velocity and turbulence intensity and decrease of temperature of room air will increase the heat loss from human body and may cause draught discomfort at comfortable room temperature and in contrary will be beneficial for occupants' thermal comfort in warm environment. However, air movement may increase eye dryness and irritation [9]. Yang et al. [12] exposed human subjects to individually controlled airflow with constant and fluctuating (0.1, 0.2 and 0.3 Hz) velocity. The subjects felt more distracted when exposed to the flows with fluctuating velocity than the flow with constant velocity.

The exposure of eye to the indoor air is result of complex interaction of flows at the face region, e.g. the interaction of the locally applied air movement (cooling fans or PV) and free convection flow around human body at face region. The interaction depends on several factors, including direction, velocity, etc. of the locally applied air movement, the strength of the free convection flow which depends on the surrounding air temperature, body posture, etc. The airflow interaction defines the temperature, relative humidity, pollution level, magnitude of velocity and its direction, turbulence intensity and frequency of velocity fluctuations, etc. at the vicinity of the eye. The combined effect of these factors on eye discomfort has not been studied.

Comprehensive experiments on human response to air movement at warm environment was performed comprising thermal sensation, perceived air quality, SBS symptoms, eye symptoms, etc. In this paper only the results related to the impact of air movement direction, oscillation and temperature on eye discomfort and tear film quality are presented and discussed.

2. Method

The experiments were carried out at the International Centre for Indoor Environment and Energy (ICIEE) at the Technical University of Denmark (DTU). Two adjacent climate chambers with separate control of temperature and humidity were used. The chambers were ventilated with upward flow of clean outdoor air supplied from the entire perforated floor at very low velocity (lower than 0.1 m/s). Two workstations (desk with chair, PC and desk light) separated by a partition were set in each chamber.

Three devices for providing local air movement for cooling were used during the experiments: large desk fan – LDF (40 W), a small desk fan (2.5 W) powered by laptop computer – USBF and a personalized ventilation supplying air from desk front edge – PV (Figure 1). The fans supplied air from front to face (LDF and USBF) or from the side of the left arm toward the chest (USBF) and their rotation speed, i.e. the velocity of the generated airflow, was under individual control of user. The occupant had control over the PV airflow rate as well as its direction to be against the chest, the breathing zone or both. The devices moved room air.

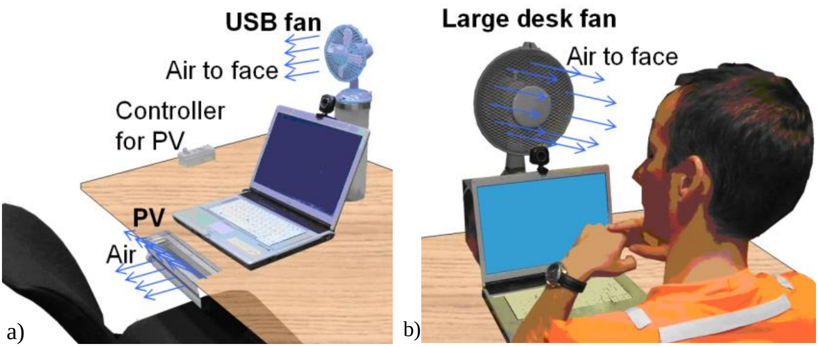

Fig. 1 Devices used for generating air movement: a) USB Fan & PV air supply diffuser installed on the front edge of the desk; b) Large Desk Fan

Twenty four male subjects, all university students were exposed to nine conditions. Only subjects without glasses and lenses participated in the experiment. At room air temperature of 25 °C and relative humidity of 50 % the subjects were exposed for 30 min to three conditions: without elevated air movement (velocity <0.1 m/s), with oscillating (in horizontal plan) USBF generating airflow cooling the face and no-oscillating USBF generating airflow against the face. At 30 °C and 50 % RH the subjects were exposed for 30 min to six conditions: without elevated movement, USBF with and without oscillation generating airflow directed toward the face, USBF without oscillation generating airflow directed toward the chest, oscillating (in horizontal plan) LDF generating airflow cooling the face, LDF without oscillation generating airflow toward the face and personalized ventilation. Eye tear film samples were taken at the beginning and the end of exposures and their quality was analyzed. Eye irritation and dryness was reported by the subject on computerized questionnaires. Numerous other questions related to subject's thermal sensation, PAQ, air movement, etc. were included in the questionnaires. The subjective response to these questions is not presented and discussed in this paper.

During the experiment subjects were dressed with T-shirts, panties, long trousers, stockings and light shoes.

Samples of tear mucus film were taken in order to assess the integrity and quality of the tear film. The samples were taken during the exposure in the chamber in accordance with the procedure of the tear ferning test [13]. The pictures of the crystallized tear film patterns were examined visually (under microscope), photographed and saved on PC. Later, the pictures were sorted into four categories according to the closeness and branching frequency of the fern patterns (Rolando 1984) as shown in Figure 2. Samples in Grade I and Grade II were classified as indicating a 'healthy eye' – no problems with tear film stability, while Grades III and IV were classified as indicating an 'unhealthy eye' – problems with tear film stability. In order to decrease the subjectivism the collected pictures were sorted by two persons and the discrepancies were examined and the grading was corrected. Before the main experiment the impact of environmental factor (temperature and relative humidity) and time on treatment of the tear film samples was investigated. In a climate chamber several samples were collected from a person at 30 °C and 50 % RH at the same time. One sample was examined in the chamber approx. after 5 min, one was examined in the chamber but after 25 min, after 5 min one sample was taken out of the chamber where temperature was 23 °C and 30 % RH and was immediately examined and one (sample) was kept outside the chamber and examined after 25 min. Four persons classified the taken photographs of the samples. No difference between crystallization patterns of the samples treated in different way was found.

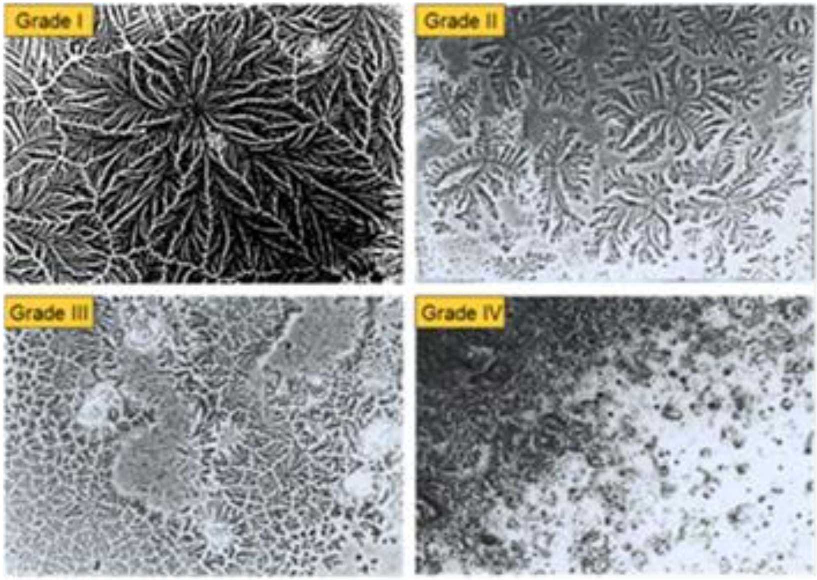

Fig. 2 Examples of the four Grades of tear film quality [13].

3. Results

Figure 3 shows the tear film quality at the end of the exposures to different conditions. No big differences in tear film quality of the samples taken during the exposures exist. Nevertheless it may be seen that in absence of elevated movement the increase in air temperature from 25 °C to 30 °C shows tendency to decrease the eye tear film quality (Grades I and II together are considered as good quality and Grades III and IV as a bad quality). The use of large desk fan blowing air constantly toward the eye deteriorated slightly the eye tear film quality while use of oscillating fans tended to improve the quality compared to the condition without air movement.

The change in eye tear film quality as a result of the exposures is shown in Figure 4. The results show that for some subjects the exposure had positive impact on tear film quality and for others negative impact. There were also subjects with eye tear film quality unaffected by the exposure. A tendency for improvement of the tear film quality at 25 °C can be seen when a weak air movement was applied toward the face. Also it seems that oscillation of the air movement were beneficial.

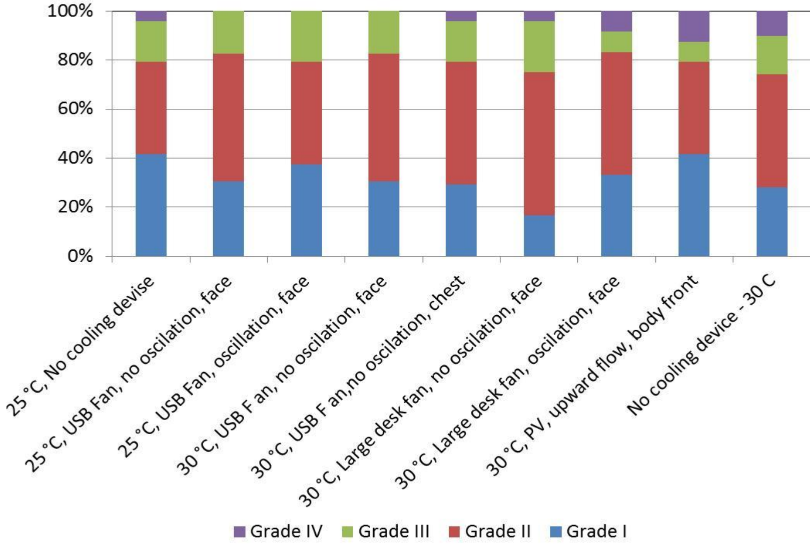

Fig. 3 Tear film quality at the end of the exposures

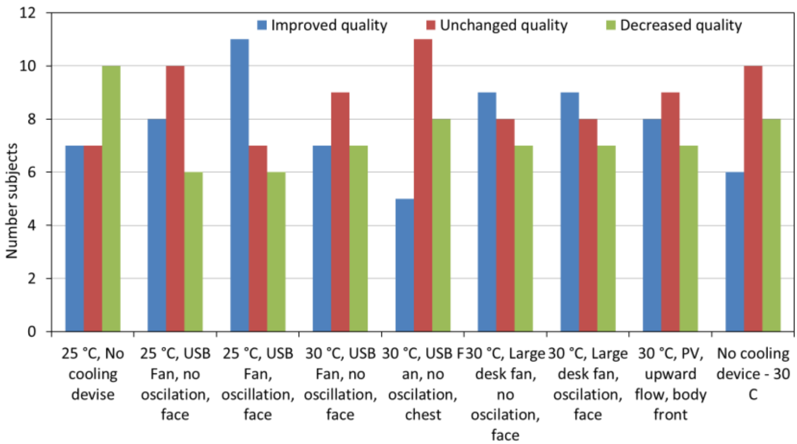

Fig. 4 Change of the tear film quality from the beginning to the end of the exposures

The results on eye irritation are shown in Figure 5. The number of subjects who reported eye irritation at the beginning and the end of the exposures is compared. The number of subjects with eye irritation decreased slightly only in the use of USBF generating flow to the chest at 30 °C and remained unchanged at 25 °C when a USBF was generating weak oscillating flow toward the face. Under all other conditions the air movement increased the eye irritation. Of the flows without oscillation (USBF, LDF, PV upward flow) the upward flow generated in front of the person toward the face caused least increase of irritation.

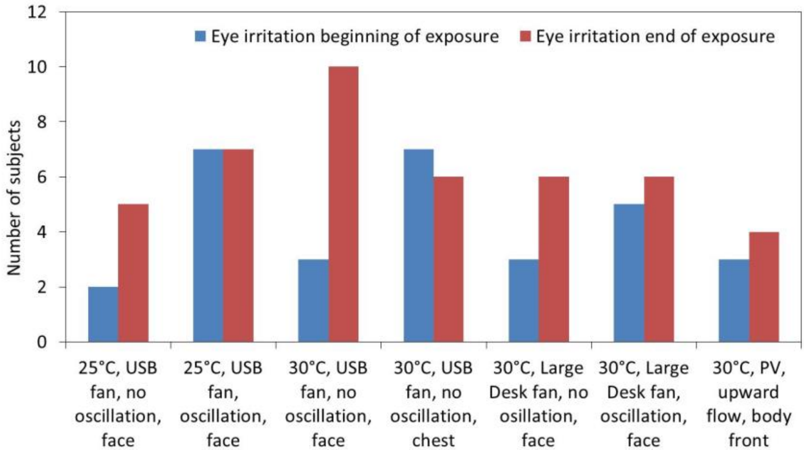

Fig. 5 Number of subjects reporting eye irritation at the beginning and the end of the exposures

During the exposures subjects reported on eye dryness sensation. Figure 6 shows the number of subjects with increased, unchanged and decreased eye dryness sensation at the end of the exposures. The elevated air movement increased the eye dryness with all cooling devices. Eye dryness increased more at 25 °C than at 30 °C. The number of subjects with increased eye dryness was almost the same as the sum of subjects with unchanged and decreased eye dryness. The only exception was with USB fan providing airflow toward the chest. Also the Large Desk fan with oscillation and the upward airflow from the PV caused less eye irritation compared to the flows blowing constantly to the face.

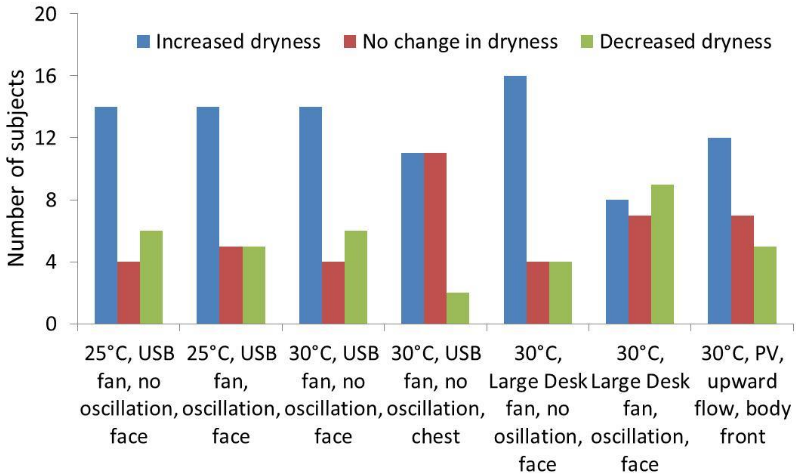

Fig. 6 Impact of the exposures on eye dryness sensation

4. Discussion

Present results concur with previous findings that increase of air temperature deteriorates tear film quality; tear film quality showed tendency to deteriorate when room air temperature increased from 25 °C to 30 °C. No substantial impact of airflow direction was identified; tear film quality was the same with airflow directed against the face and with upward airflow from the chest to the face. The left/right oscillation of the face cooling airflow improved tear film quality compared to airflow without oscillation but this was observed only at air temperature of 25 °C.

Air movement increased eye irritation, both at comfortable (25°C) and at warm (30°C) environment. Airflow direction had an impact on eye irritation. Airflow from front increased eye irritation more than upward airflow from front of the body. Left/right oscillating airflow from front caused less eye irritation than airflow without oscillation from front. This result supports the present design of the desk fans having oscillation mode.

Eye dryness is one of frequently reported complains from building occupants. The results of the present study supported the results of previous studies [10, 11] that air movement increases the perception of eye dryness. It was revealed in the present study that airflow direction is also important for the eye dryness. In the case of airflow from front toward the face the eye dryness increased substantially more than in the case of upward airflow from the front of the body toward the face. The results also show that airflow to the face causes less eye dryness when it is oscillating in horizontal plan compared to when it is not oscillating.

The energy saving strategy of maintaining high indoor air temperature and improving occupants' comfort (thermal comfort and perceived air quality) by elevated air movement under individual control should be carefully considered. Occupants, in order to avoid eye discomfort may decrease the velocity or change the direction of the cooling flow, leading to less improvement in their thermal comfort. This may result in dissatisfaction with the thermal environment which will have negative impact on the work performance. In this study the personalized ventilation was used to generate air movement tangentially to the chest and face, expecting that the negative effect of the flow pressure and thus eye irritation and dryness will decrease in comparison to the case of airflow from front. The expectation was confirmed. The use of personalized ventilation providing air with temperature few degrees lower than the room air temperature will increase the local cooling and will improve the thermal comfort at low velocity of the flow leading to decrease in eye discomfort. Another advantage in use of personalized ventilation compared to the use of cooling fan (moving polluted and warm room air) is the possibility to supply clean personalized air which will decrease the SBS symptoms [4]. Personalized ventilation can be applied in "ductless" mode allowing for local cleaning and disinfecting of room air [14, 15, 16].

5. Conclusions

The present study confirmed that increase in room air temperature may have negative impact on tear film quality.

The increase of air movement increases eye irritation and eye dryness.

Airflow direction has impact on eye irritation and dryness. Airflow from front toward the face causes more eye irritation and increases eye dryness compared to upward airflow from front of the body toward the face.

Oscillating airflow causes less eye irritation and increases less the eye dryness compared to airflow without oscillation directed toward the face.

6. Acknowledgment

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