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Prevalence of objective eye manifestations in people working in office buildings with different prevalences of the sick building syndrome compared with the general population

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Summary. A cross-sectional clinical epidemiological study was carried out among 169 office workers in four Copenhagen town halls with different prevalences of the sick building syndrome. The results were compared with those in 112 subjects randomly selected from the general population. Biomicroscopic eye manifestations, such as premature break-up of the precorneal tear film, absence of foam at the inner eye canthus and epithelial damage of the bulbar conjunctiva, were investigated together with self-reported eye complaints. Although intercorrelated, the objective eye manifestations independently were statistically associated with self-reported eye complaints in office workers. The prevalence of the objective eye manifestations was significantly elevated in office workers compared with the general population and most pronounced for the buildings with a high prevalence of the sick building syndrome ($P < 0.001$). In the general population, subjects with a non-industrial occupation, including office workers, had a significantly higher prevalence of objective eye manifestations than those with an industrial occupation ($P = 0.03$), but the prevalence was still significantly lower than that among the office workers in buildings with a high prevalence of the sick building syndrome ($P < 0.001$). Since possible confounders were found not to explain the difference in prevalence of objective eye manifestations and complaints among the two populations, it is concluded that the office environment (buildings and/or type of office work) promotes these objective changes accompanied by self-reported complaints.

Key words: Sick building syndrome – Eye irritation – Biomicroscopically dry eyes

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Introduction

Irritation and dryness in the eyes together with blocked or runny nose, dry throat, headache and lethargy, and dry skin are complaints today recognized as an important part of the sick building syndrome (SBS) [2]. There is increasing evidence that these complaints develop in people working in office buildings and that both the indoor air quality and the type of office work are of importance [3, 8, 16, 17]. However, one might respond that these symptoms are common in the general population.

In several previous reports we found a good correlation between self-reported eye complaints and biomicroscopically observed eye changes, such as premature break-up of the precorneal tear film, absence of foam at the inner canthus and epithelial damage of the bulbar conjunctiva [4, 6, 7]. As the objective eye changes have been found to be intercorrelated [6], one aim of this study was to estimate the odds ratios for eye complaints in relation to each of the above eye manifestations, using a logistic regression analysis. Another aim was to compare (a) the prevalence of objective eye manifestations in people working in office buildings with different prevalences of the SBS and (b) the prevalence of such eye manifestations in the general population.

Material and methods

Buildings. Four town halls in Copenhagen were included in the present study. They were selected on the basis of observations made 1 year previously among 14 town halls participating in several investigations on the indoor climate performed by the Danish indoor study group [15]. The four buildings were selected because they represented buildings of different age, different types of ventilation system and different prevalences of SBS. At the time of the

Table 1. Prevalence of building-related symptoms 1–2 weeks before the clinical investigation

Town hall	All employees				Clinically examined[d]	
	No.	General symptoms[a]	Mucous membrane symptoms[b]	Eye complaints[c]	No.	Eye complaints
I	299	24%	35%	22%	44	26%
II	195	55%	70%	43%	46	47%
III	314	48%	65%	40%	50	42%
IV	36	50%	61%	50%	24	54%

[a] Headache or fatigue several times a week
[b] Eye, nose or throat irritation several times a week
[c] Itching, smarting or irritation several times a week
[d] Four subjects did not participate in the questionnaire investigation

present clinical investigation at the beginning of 1985, the prevalence of SBS in one of the buildings was about half that in the other three (Table 1).

Subjects. The study population comprised 169 office workers from the four town halls. They were selected from the total population employed 1 year before the present investigation. A random but stratified sample of employees with eye complaints several times a week and without eye complaints was drawn among the men and women working in town halls I, II and III. This procedure was chosen to ensure that the study group contained a sufficient number of subjects with and without complaints. No subjects were drawn from the intermediate group with eye complaints only once a week to once a month, but this group constituted only 11% of all employees. From town hall IV, which had only 32 employees at the time of investigation, all the employees were invited to participate. A total of 222 subjects were invited and the response rate was 76%.

Eighteen subjects did not participate because they had retired or moved to workplaces outside the town hall, and 16 because of sickness or vacation. Only four subjects did not wish to joint the investigation. Three subjects were excluded because of eye disease and nine subjects because of use of contact lenses. Further three subjects had to be excluded because of nervous blinking, which makes the clinical examination impossible to perform.

The control group comprised 112 persons from the Glostrup Population Studies on the prevalence of cardiovascular symptoms in an average Danish population. The participants in these studies were drawn randomly from the Central Person Register among all persons living in the western part of Copenhagen County and aged 30, 40, 50 or 60 years. The subjects in the general population were divided by occupation into non-industrial and industrial workers and not employed.

The group with a non-industrial occupation included office workers and the group not employed included students, self-employed, unemployed and elderly or sick subjects without occupation. The control group originally consisted of 123 subjects called in for the cardiovascular investigation on nine consecutive days, but ten were excluded because of known eye disease or use of contact lenses. Furthermore, one subject had to be excluded owing to nervous blinking. Details of both study groups are given in Table 2.

For the estimation of the prevalence of the different signs and symptoms in the office population, the weighted sample was taken into account.

Questionnaire on eye complaints. The participants answered a new questionnaire on eye complaints to ensure that any objective changes could be correlated to the actual eye complaints. The study group was asked whether they experienced one or several of the following symptoms from the eyes more than once a month: tiredness, itching, smarting, irritation, dryness, lachrymation or redness. If yes, they were asked how often they experienced the symptoms: less than once a week, once a week, several times a week or daily.

Table 2. Characterization of study population

	Office population[a] No. (%)	General population[b] No. (%)
Age		
30 (19–34)	53 (31)	25 (22)
40 (35–44)	51 (30)	33 (30)
50 (45–54)	35 (21)	33 (30)
60 (55–69)	30 (18)	21 (19)
Gender/females	107 (63)	59 (53)
Females using eye make-up	66 (62)	37 (63)
Current smokers	79 (47)	57 (51)
Use of video display terminal >1 h/day	61 (36)	15 (13)
Higher education or leading position	56 (33)	–
Occupation		
Non-industrial	169 (100)	66 (60)
Industrial	0	23 (20)
Not employed	0	23 (20)

[a] Total number = 169
[b] Total number = 112

Ophthalmological examination. This part of the study took place immediately after the subjects had answered the questionnaire. The examiner did not know the result of the questionnaire study. The investigations on office workers were performed in the office buildings. All ophthalmological examinations were performed between 10 a.m and 3 p.m. The ocular tests were performed in each subject in the following order using a binocular eye microscope (Nikon FS-2 slit lamp):

1. *Foam formation* was examined in the inner canthus of the right eye. Diffuse light was achieved by a wide open slit and maximum magnification (×30). If three or more agglomerated gas bubbles were observed, presence of foam was recorded [6].

2. *Break-up time* of the precorneal tear film was measured in cobalt-filtered light after instillation of 10 µl fluorescein 1%. A spontaneous rupture occurring less than 5 s after a blink was considered abnormal, one occurring between 5 and 10 s as borderline, and one occurring after more than 10 s as normal [4].

3. *Epithelial cell damage* was visualized as clusters of jointly stained dots on the temporal or nasal conjunctiva 1 min after instillation of 10 µl lissamine green dye 1%. Presence of more than 50

dots in a cluster was considered abnormal, between 10 and 50 dots as boderline, and below 10 dots as normal [4].

Objective eye index: "office eye syndrome". On the basis of results on foam formation, break-up time and epithelial cell damage, office eye syndrome was considered present if at least two of the three tests were abnormal.

Statistical methods. Prevalence of ocular signs and symptoms in the different populations was compared by the chi-square test. Kendall's tau B rank correlation coefficient was used to analyse the association between occurrence of objective eye manifestations or self-reported eye complaints and each of the following possible confounders: age, sex, use of eye make-up, smoking habits, work at a computer terminal for more than 1 h/day, permanent use of glasses, presence of menstruation, sleeping hours the previous night and higher education/leading position. The multifactorial effect was analysed in a logistic regression model. Included in the model were those confounders significantly correlating with one or several of the ocular tests (see Table 4). The ratio of reporting of eye complaints in relation to eye changes was also analysed by a logistic regression model. In all statistical analyses two-tailed tests and a level of significance of 5% were used.

Results

The prevalence of biomicroscopic eye manifestations and self-reported eye complaints is shown in Table 3. The prevalence of the various eye manifestations was significantly elevated in one or several of the town halls and most pronouncedly in the buildings with a high prevalence of the sick building syndrome (high SBS area). Especially the index including all three objective ocular tests, used to assess office eye syndrome, showed a consistent pattern in the town halls, in that the prevalence was significantly higher in the buildings with a high prevalence of SBS than in the general population. Although not statistically significant, the prevalence in the town hall with a low prevalence of SBS (low SBS area) was found to lie between that found in the general population and that in the town halls with a high prevalence of SBS. Table 3 also shows the prevalence of biomicroscopical eye manifestations and self-reported eye complaints in relation to occupation in the general population. A consistent pattern was found, with a higher prevalence of signs and symptoms in employees with a non-industrial occupation compared with employes with an industrial occupation. The difference was statistically significant only for biomicroscopically determined office eye syndrome.

The confounder control was carried out in two steps. Table 4 shows the correlation between the different signs and symptoms and possible confounders using the Kendall's tau B correlation coefficient. Included in the table are only those confounders (age, sex and use of eye make-up) significantly correlated with one or several of

Table 3. Prevalence of biomicroscopic eye manifestations and self-reported eye complaints

Population	Premature break-up of tear film (< 5 s)	Epithelial damage (> 50 dots)	Absence of foam (< 3 bubbles)	Office eye syndrome[a]	Self-reported eye-complaints[b]
Office workers: high SBS area[c] ($n = 125$)	42%**	27%	85%**	50%**	42%*
Office workers: low SBS area[d] ($n = 44$)	27%	20%	77%**	37%*	33%
General population ($n = 112$)	20%	21%	43%	21%	27%
Non-industrial occupation ($n = 66$)	18%	27%	49%	26%	27%
				$P = 0.03$	
Industrial occupation ($n = 23$)	13%	13%	35%	9%	17%
Not employed ($n = 23$)	30%	13%	35%	17%	35%

* $P < 0.05$; ** $P < 0.001$ (tested against general population)

[a] At least two of the following three ocular tests were abnormal: premature break-up of tear film, epithelial damage and absence of foam

[b] Tiredness, itching, smarting, irritation, dryness, lachrymation or readness several times a week

[c] Prevalence of eye complaints and mucous membrane and general symptoms ≥ 40%

[d] Prevalence of eye complaints and mucous membrane and general symptoms ≤ 35%

Table 4. Correlation between ocular tests and possible confounders[a]

Ocular test	Break-up time		Epithelial damage		Absence of foam		Eye complaints	
	Office workers	Controls	Office workers	Controls	Office workers	Controls	Office workers	Controls
Age	0.18	−0.05 NS	−0.14	−0.10 NS	−0.06 NS	−0.23	0.04 NS	−0.01 NS
Sex	−0.05 NS	−0.19	−0.02 NS	−0.02 NS	−0.22	−0.24	−0.16	−0.25
Make-up users	−0.07 NS	0.13 NS	0.08 NS	0.10 NS	0.14 NS	0.35	0.01 NS	0.01 NS

NS, Not significant

[a] Included are those possible confounders significantly correlated (Kendall tau B, $P < 0.05$) with one or more of the ocular tests

Table 5. Odds ratios for experiencing of eye complaints several times a week in relation to objective eye manifestations

Ocular test	Office workers		Controls	
	OR[a]	95% CI[b]	OR[a]	95% CI[b]
Premature break-up of tear film (<5 s)	2.28	1.19–4.36	0.76	0.24–2.37
Epithelial damage (>50 dots)	1.89	0.91–3.92	0.92	0.32–2.65
Absence of foam (<3 bubbles)	2.94	1.08–7.96	1.09	0.46–2.62

[a] Odds ratios obtained from logistic regression model containing all three ocular tests
[b] 95% confidence interval

the ocular tests. Other possible confounders, such as work at a computer terminal for more than 1 h a day, smoking habits, permanent use of glasses, presence of menstruation, sleeping hours the previous night or higher education/leading position, showed no significant correlation. In the next step age, sex and use of eye make-up were included in a logistic regression analysis. None of the confounders was then found to be statistically significant, but a high odds ratio was found in both office workers and controls between use of eye make-up and absence of foam (2.6 and 3.1 respectively).

Table 5 shows that premature break-up of the precorneal tear film, damage of the conjunctival epithelium and absence of foam independently had a significant (or near-significant) influence on the reporting of eye complaints in the office workers, but not in the subjects from the general population.

Occurrence of all three eye manifestations in subjects from the general population ($n = 6$) was significantly associated with experiencing of eye complaints at least once a month ($P < 0.01$).

Discussion

Our study is not only the first to document an elevated prevalence of objective eye manifestations in people working in buildings with a high prevalence of SBS, as compared with that in the general population. It is also the first to document that the prevalence of self-reported complaints is higher in office workers than in the general population. Other studies have dealt only with complaints among office workers in buildings with different characteristics [3, 8, 16] or among the general population alone [12]. Our results strongly indicate that the office environment (buildings and/or type of office work) promotes both the eye changes and the symptoms, if selection bias and the influence of confounders can be excluded. Selection bias can occur as a result of withdrawal of subjects from the original cohort or incorrect study design. The number of withdrawn subjects was about three times greater in the group with eye complaints [6] and since most of them had retired or were sick, it seems unlikely that they represented "healthy workers" without the objective eye manifestations found in the group with eye complaints several times a week. Another potential source of selection bias could have been the fact that the intermediate group with eye complaints once a week to once a month was not represented in the office population. However, this group constituted only 11% of the employees; earlier reports on the correlation between eye complaints at the time of study and occurrence of the three eye manifestations examined indicated that this group would have a prevalence very near the estimated mean for office workers [4, 6]. Furthermore, in the investigation performed 1–2 weeks before the present one and before the subjects had been given any information about their possible participation in the present clinical investigation, the prevalence of eye complaints in the clinically examined group was representative of that in all employees in the buildings, when the weighted sample was taken into account (Table 1). On the other hand, the existence of "sick office workers" in the general population is a possibility. The difference between subjects with industrial and non-industrial occupations in the general population indicates that this could be of importance. Both the withdrawal in the office population and the existence of "sick office workers" in the control group would cause underestimation of the true effect of the office environment on the eyes.

Several interdisciplinary studies have documented an elevated occurrence of eye irritation in air-conditioned office buildings [10], but indoor air pollutants such as volatile organic compounds and respirable dust have also been found to be of significance for self-reported eye irritation in non-industrial buildings [9, 11]. Chemical stimulation of the trigeminus nerves in the eyes has been suggested as an explanation for the eye irritation in the SBS [1]. Our finding of a correlation between eye complaints and absence of foam, premature break-up of the precorneal tear film and damage of the conjunctival epithelium indicates that subjects with these objective eye manifestations have eyes hypersensitive for irritants. The logistic regression analysis shows that the three objective eye manifestations independently influenced the experience of eye symptoms in the office workers. This indicates that each of the eye manifestations contributed to the hypersensitivity, probably by laying bare the nerve ends of the trigeminal nerve.

However, our investigation also shows that it is not only a question of simple irritants in the office environment. The prevalence of eye manifestations was significantly elevated in the office workers compared with the general population, indicating that the office environment (buildings and/or type of office work) in itself promotes these eye changes.

Absence of foam on the one hand and premature break-up of the tear film and epithelial damage on the other have been found to be intercorrelated in both office workers and the general population [6]. It is diffi-

cult to decide which manifestation is primary and which is secondary; however, the fact that the difference in prevalence of eye manifestations between the office workers and the general population was found to be most pronounced for absence of foam indicates that absence of foam is the primary manifestation.

In a recent follow-up study we have documented decreased thickness of the outer thin fatty layer of the precorneal tear film in office workers [5]. Furthermore, the thickness of the fatty layer correlated significantly with an index including premature break-up time and epithelial damage. Both the fatty layer of the precorneal tear film and foam at the inner canthus consist of fat, most likely from the meibomian glands [13, 14]. This indicates that insuffient meibomian fat may be of importance for development of the office eye syndrome. We have previously postulated that surface-active/lipophilic volatile organic compounds may be of importance by decreasing the foam as well as the fatty layer of the precorneal tear film [5], but other factors influencing the lipids, including mild blepharitis, cannot be excluded.

Preliminary results from our laboratory indicate that the unstable tear film and epithelial damage of the conjunctiva are to a great extent chronic in office workers, at least if the subjects stay in the office environment. We do not know the prognosis in subjects leaving the office environment or after improvement of the indoor air quality. Therefore, we do not know to what extent the modern office environment produces an increased number of office workers with dry eyes when they have retired from work. Further studies are needed in this area.

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