Effects of Temperature and Humidification in the Office Environment

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ABSTRACT. In this investigation, the authors evaluated the relationship between temperature and (a) Sick Building Syndrome symptoms and (b) workers' perceptions of air dryness in environments with and without humidification. The authors studied the average intensity of symptoms and perceptions of dry air relative to room temperature in humidified and nonhumidified conditions. During the 6 wk of the experiment, 2 wings of the building were humidified one-by-one for 1 wk, followed by a week without humidification. A total of 230 daily questionnaires were completed during the nonhumidified period, and 233 were completed during the humidified period. The results were analyzed with linear regression analysis, and the average intensity of dryness symptoms and sensations of dryness increased with each unit increase in temperature above 22 ºC, both in the humidified and nonhumidified conditions. Sick Building Syndrome symptoms increased relative only to temperature during the period of no humidification. In conclusion, temperatures above 22 ºC caused increased dryness symptoms and a sensation of dryness, independent of humidification. The overall intensity of Sick Building Syndrome symptoms increased only when indoor air was not humidified.
<Key words: humidification, Sick Building Syndrome, temperature>

IN AN EARLIER STUDY, we found that if the indoor temperature was too high, there was an increase in symptoms related to Sick Building Syndrome (SBS) and an increased sensation of dryness.[1] Air humidification tended to alleviate irritation symptoms of the skin and mucosa, as well as the sensation of air dryness.[2,3] In the present study, we assessed the effects of room temperature on SBS-related symptoms and the sensation of dryness in nonhumidified and humidified conditions.

Method

Study design and outcomes of interest. In January and February of 1989, we conducted a crossover trial in the Pasila Office Center in Helsinki, Finland, to assess the effects of steam humidification on workers' symptoms and perceptions of air dryness. A detailed description of the building, its ventilation, and indoor air measurements can be found in a previous publication that describes the humidification trial.[3]

The study took place in 2 wings of the building. During the experiment, after a random selection, 1 of the wings was humidified and the other remained nonhumidified. After 1 wk, the humidification was switched. During the total study period of 6 wk, the population in the 2 wings was exposed to humidification for 3 1-wk periods and to nonhumidified conditions that corresponded to 3 1-wk periods. Determinants of interest were temperature in each office and air humidification. In a baseline questionnaire administered at the beginning or the study, we obtained information about personal characteristics and variables concerning work-related factors and the work environment.

During the 6-wk experiment, the participants completed a daily structured questionnaire that contained queries about symptoms of acute respiratory illness, time spent in the office, symptoms of dryness (scale of 0 to 3), and the sensation of dryness (scale of 1 to 5) during each work day. The outcomes of interest were symptom scores, which we calculated with the information provided in the daily symptom reports: (1) *dryness symptom score* (0–12), which included skin symptoms (i.e., dryness, irritation, or itching), nasal dryness, and pharyngeal dryness; and (2) *SBS symptoms score* (0–6), which included combined symptoms of SBS (i.e., skin, eye, nasal, and pharyngeal symptoms, headache, and lethargy). The *sensation of dryness* was coded as 1 (too humid) to 5 (too dry).

At the beginning of the study, each of the two groups studied included 180–190 clerical workers. Individuals were eligible for the study if they did not have or use a humidifier in their office. Those who had completed the baseline questionnaire were eligible for participation in the experiment. In the final analyses, we included individuals who had filled in the baseline questionnaire acceptably and who had spent at least 2 hr in the office during which time they had suffered no symptoms of acute respiratory illness.

Statistical methods. We calculated the mean scores of each outcome as a personal mean value for the nonhumidified period and humidified period separately. Each corresponding room temperature (ºC) was calculated as a mean of the readings of the thermometer in each participant's office.

To grasp the direction and strength of the association of outcomes and temperature during and without humidification, we fitted a multiple linear-regression model for each outcome. In addition, we used analysis of covariance to calculate adjusted means for the outcomes in 5 temperature categories. Given the skewed distributions and heteroscedasticity of the outcomes,[4] we assessed the statistical significance of the linear association by the method of Cochran-Mantel-Haenszel (CMH).[5] For the CMH method, we classified outcomes in 3–4 categories that contained approximately equal numbers of participants. Calculations were made with a personal computer and version 6.12 SAS statistical software.

Results

Study population and indoor air quality. At least one diary was returned by each of 230 workers during the nonhumidifed period and by 233 workers during the humidified period. There were no statistically significant differences between the nonhumidified and humidified periods with respect to personal characteristics or with respect to characteristics of the work environments. Numbers of subjects, mean temperatures, and corresponding relative humidities are provided in Table 1.

Temperature effects. The regression coefficients indicating change in the outcome variable per 1 ºC of temperature during the nonhumidified and humidified periods from the multiple linear-regression models are given in Table 2. The statistical significance of the association, expressed as a *p* value in Table 2, is the result of CMH analysis. The corresponding adjusted

Table 1.—Characteristics of Environmental Conditions in Various Temperature Categories

	Nonhumidified air						Humidified air					
	Population		Temperature (ºC)		RH (%)		Population		Temperature (ºC)		RH (%)	
Temperature category (ºC)	*n*	%	$\bar{x}$	*SD*	$\bar{x}$	*SD*	*n*	%	$\bar{x}$	*SD*	$\bar{x}$	*SD*
< 21	20	8.7	20.3	0.69	29.0	2.48	8	3.4	20.2	0.57	37.2	3.53
21– < 22	54	23.5	21.5	0.30	26.2	1.24	45	19.3	21.2	0.32	34.4	1.78
22– < 23	88	38.3	22.4	0.33	25.0	1.23	98	42.1	22.3	0.31	32.9	2.34
23– < 24	55	23.9	23.3	0.30	23.5	0.88	66	28.3	23.3	0.34	30.7	2.14
≥ 24	13	5.6	24.2	0.27	22.9	1.19	16	6.9	24.2	0.29	28.2	1.44
Total	230	100.0					233	100.0				

Notes: RH = relative humidity, $\bar{x}$ = mean, and *SD* = standard deviation.

Table 2.—Association between Room Temperature and Symptoms and Air Dryness in Nonhumidified and Humidified Conditions

Symptoms	Nonhumidified air			Humidified air		
	β	*SE*	*p*	β	*SE*	*p*
Dryness symptoms (covariates = sex, atopic tendency, stress; CMH categories = 0, > 0–1, > 1)	0.104	0.110	.13	0.195	0.118	.013
SBS symptoms (covariates = sex, atopic tendency, stress; CMH categories = 0, > 0–2, > 2)	0.112	0.084	.078	0.185	0.090	.12
Sensation of dryness (covariate = sex; CMH categories = 3, > 3–3.8, > 3.8)	0.122	0.040	.19	0.059	0.046	.085

Notes: Regression coefficients are from linear regression, controlling for factors in the table. Statistical significance from CMH procedure representing a linear trend between the outcome and temperature, controlling for the covariates given here. Nonhumidified, *n* = 230; humidified, *n* = 233. *SE* = standard error, CMH = Cochran-Mantel-Haenszel (method), and SBS = Sick Building Syndrome.

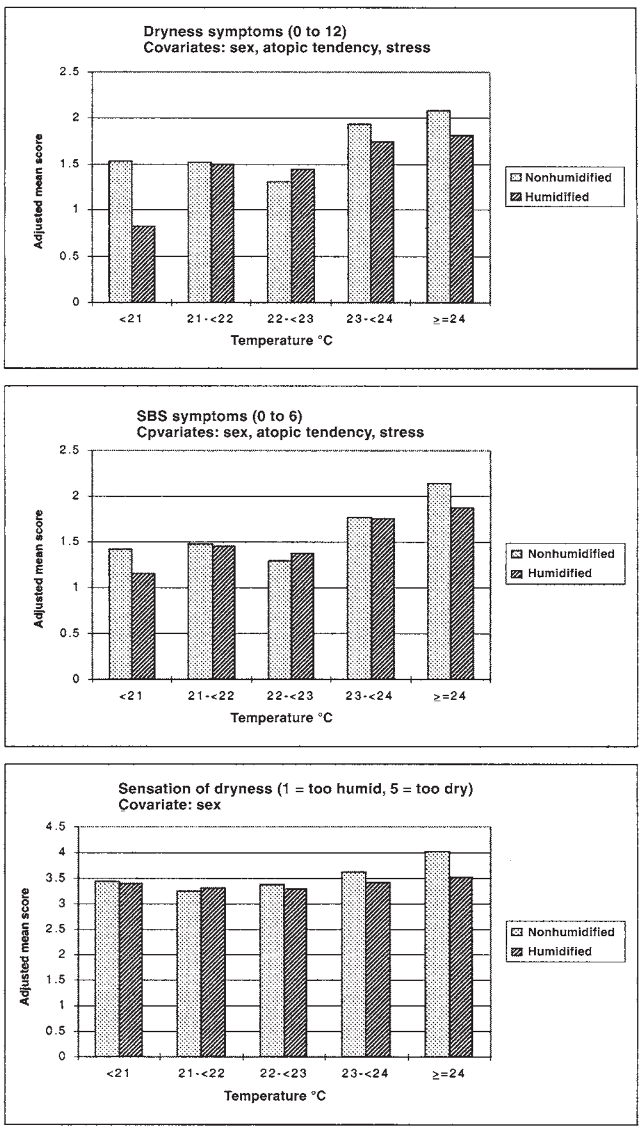

Fig. 1. Adjusted mean scores of dryness symptoms, Sick Building Syndrome symptoms, and the sensation of dryness in 5 temperature categories.

means of the outcomes from the covariance analysis in the 5 temperature categories during both periods of study are shown in Figure 1.

Multiple linear regression produced an ascending trend for temperature for dryness symptoms and SBS symptoms, as well as for the sensation of dryness. The SBS symptoms and the sensation of dryness exhibited a descending trend in the two lower temperature categories, and an ascending trend occurred at temperatures that exceeded 22 ºC. The CMH analysis also indicated a significant linear trend for dryness symptoms (CMH—nonhumidified conditions, $p = .024$; CMH—humidified conditions, $p = .033$) and for the sensation of dryness (CMH—nonhumidified conditions, $p = .013$; CMH—humidified conditions, $p = .006$). The ascending trend we noted for temperatures in excess of 22 ºC was statistically significant for SBS symptoms during the nonhumidified period (CMH, $p = .042$). The symptoms were the most intense in the majority of temperature categories during the periods of nonhumidification.

Discussion

Validity of results. The nonexperimental study design raised the possibility that selection bias (i.e., people chose offices with a most-suitable temperature) occurred. The crossover design of this study eliminated such a problem. The opening of windows likely provided compensation for the temperature rise caused by humidification. Both mechanisms tended to dilute the effects of humidification and temperature on the symptoms and perceptions we studied.

Synthesis with previous knowledge. Researchers have studied the role of high indoor air temperatures and/or humidification as determinants of symptoms and perceptions in nonindustrial workplaces and in several types of settings. In this study, we compared our results with those reported in a summary presented by Mendell and Smith,[6] as well as with results of reports published subsequently. Consistent with the present findings, the entity defined as SBS symptoms was increased during high-temperature conditions in 4 of the 7 studies in which this issue was addressed.[1,7–9] In

3 of the 7 studies, investigators found no association.[10–12] In none of these studies did researchers find a decrease in SBS symptoms with high temperatures. High temperature increased the sensation of dryness.[1,3,7] Humidification reportedly decreased the prevalence of SBS symptoms or dryness of airway symptoms only, in 5 of 11 assessment studies.[2,3,9,13,14] In 3 of 11 studies, an increase in SBS symptoms occurred during humidification.[11,12,15] In 1 of the 11 studies, a reanalysis of 6 previous studies did not produce a correlation between humidification and SBS symptoms.[6] In the present study, we found a lower level of SBS symptoms, compared with the nonhumidified conditions, and there was an alleviation of the sensation of dryness during humidification.[2,14] We found that dryness increased more acutely as temperature increased in nonhumidified conditions.

Conclusions

The results of this study strengthened the evidence that an indoor temperature in excess of 21 ºC or 22 ºC is likely to increase dryness symptoms of the skin and upper airways and to increase the total number of symptoms than can be related to SBS syndrome. The sensation of dryness increased at higher indoor temperatures. Humidification alleviated dryness symptoms and the sensation of dryness.

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