Sudden temperature changes and respiratory symptoms—An experimental approach

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ABSTRACT

Background: *Exposure to air-conditioning systems and allergic phenotypes are consistent risk factors to develop indoor air quality (IAQ) respiratory complaints. The aim of this study was to compare the role of allergic rhinitis on respiratory complaints in individuals exposed to sudden temperature changes.*

Methods: *To address this question, a case-control challenge study was performed in a laboratory of thermal comfort evaluation with twin isolated chambers set at 14°C/57.2°F (cold) and 26°C/78.8°F (hot) temperatures. A groups of 32 patients with persistent allergic rhinitis (rhinitis group) and 16 control subjects (control group) were exposed for 30 minutes, three times alternately in the chambers. Symptoms were reported using an analog visual scale and nasal and pulmonary peak flow measurements were taken during baseline at hot and cold temperatures and after the challenge.*

Results: *The rhinitis group reported increased itching and stinging eyes when compared with the baseline during exposure to hot and cold temperatures and they also reported increased breathlessness during hot air exposure. In addition, there was a significant decrease in expiratory flow rates in this group during exposure to hot and cold temperatures that persisted for 24 hours after challenge.*

Conclusion: *This study suggests that individuals with allergic rhinitis have a lower threshold than controls to develop respiratory and ocular symptoms after air-conditioning–induced sudden temperature changes.*

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Key words: Air-conditioning, allergy, atmosphere exposure chamber, environmental exposure, occupational health, rhinitis

Indoor air quality (IAQ) is a concern of health and wellness in indoor environments within the sealed shells of modern buildings worldwide. IAQ-related problems are reported in various climatic conditions including tropical climates[1] and are considered the most common environmental health issue that clinicians face.[2] The factors associated with IAQ are multiple and have a complex interaction including temperature, humidity, air exchange rates, exposure to organic and inorganic indoor air pollution, odors, air movement, work, and psychosocial factors. The presence of air-conditioning systems,[1,3,4] and allergic condition,[5–7] are risk factors consistently associated with respiratory symptoms in IAQ epidemiological studies. The changes in the work pattern of the new office environment are characterized as dynamic, with interactive project teams and different or shared workplaces.[8] This increased movement can lead to increased exposure to different indoor and outdoor conditions with wide and sudden temperature changes.

Allergic rhinitis is a global problem affecting 10–25% of the population. It is clinically defined as a symptomatic disorder of the nose induced by a mucosal inflammation after allergen exposure of the membranes lining the nose. Symptoms of rhinitis include rhinorrhea, nasal obstruction, nasal itching, and sneezing, which are reversible spontaneously or with treatment. Individuals with allergic rhinitis also can have bronchial hyperreactivity indicated by increased airway resistance and diminished forced airflows in bronchial challenges.[9] Allergen exposure is the most potent trigger of nasal symptoms, but the nasal mucosa of the allergic population has a lower threshold to various stimuli and a diminished capacity to warm and humidify air.[10,11] Considering that allergen exposure in nonresidential and nonindustrial settings are mostly not significant,[12–14] the study of the role of air-conditioning–induced temperature changes *per se* in the atopic population could bring new insights to the mechanism of building-related complaints in settings with sudden temperature changes.

MATERIALS AND METHODS

Selection of Individuals

After the authorization of the Ethics Committee of the State University of Sao Paulo (Protocol 930/02), 48 individuals who signed a consent form were selected of allergy patients and healthy individuals. The participants in the study ranged in age from 20 to 45 years old and were not undergoing any medical treatment for chronic illnesses, including endocrine, infectious, or rheumatologic diseases. They all underwent a medical history, physical examination, and skin-prick testing with standardized allergens. The tests were performed in duplicate with epicutaneous puncture and were evaluated after 20 minutes with the following allergens extracts: *Der-*

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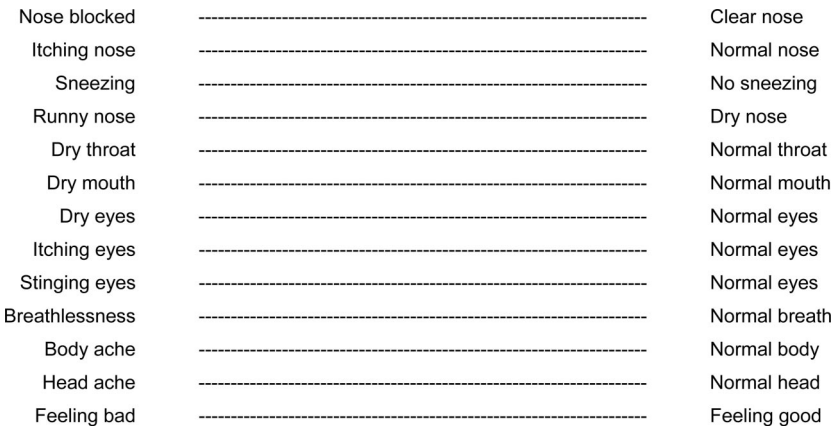

Figure 1. *Visual analogue scale questionnaire. Each line has a length of 10 cm on the original questionnaire.*

matophagoides pteronyssinus, *Blomia tropicalis*, *Aspergillus fumigatus*, *Alternaria alternata*, and dog and cat epithelium (IPI-ASAC; Brazil), according to standard procedure. Tests were considered positive for allergen sensitization with a mean arithmetic papules of >4 mm for allergens. Individuals with positive reactions to saline or negative reactions to histamine were excluded. The rhinitis group consisted of 32 individuals, 22 men and 10 women, who had allergic rhinitis (nasal pruritus, aqueous nasal discharge, sneezing, and nasal blockage), and at least one positive cutaneous test for tested allergens. All patients from the rhinitis group who had symptoms present at least 4 days/week during >8 weeks/year were classified as having persistent rhinitis according to the Allergic Rhinitis and its Impact on Asthma study criteria.[15] The control group comprised 8 men and 8 women without history or symptoms of allergic diseases and who had negative tests for allergic diseases, age matched with the rhinitis group. Individuals with evidence of viral illnesses, immunologic impairment, or use of any antihistamine or anti-inflammatory drugs 14 days before temperature tests were excluded.

Temperature Tests

The selected population dressed in standardized thermal protection clothing of 1.0 clothing units.[16] Temperature tests were conducted in twin chambers controlled for temperature, humidity, sound, light, and ventilation. The chambers had exclusive air supply from a fan coil with a nominal output of 340 m^3/hour and a chiller with a capacity of 5 tons of refrigeration. The experimental system supplied air exchange rates of >27 m^3/hour per person, which assured carbon dioxide levels in the chambers of <700 ppm. The two chambers had a temperature difference of 12°C (21.6°F), where the "hot" chamber was 26°C (78.8°F) and the "cold" chamber was 14°C (57.2°F), both with the relative humidity of the indoor air set at 60 ± 2%. Individuals were dressed accordingly at room temperature, where they filled out the scale and then were introduced into separate chambers for temperature challenges. After 30 minutes of acclimatization, they were asked to fulfill the scale and move from one chamber to the other consecutively. All participants started from cold chambers moving to hot chambers until they completed three rounds of temperature changes totaling 3 hours of challenge. After final acclimatization, the subjects were asked to fill out the scale immediately after and 24 and 48 hours after challenge. Levels of indoor pollution were monitored for biological (viable fungi spores), inorganic (total particulate matter), and personal pollutants (carbonic dioxide levels) during challenges.

Symptoms

A previously proposed reduced version of a visual analog scale was used to access IAQ-related symptoms[17] (Fig. 1). This scale consisted of 13 different questions concerning general and respiratory symptoms related to IAQ. Individuals were instructed to complete the scale by plotting their symptoms according to their intensity onto a 10-cm-long line with the extremes of perception at given intervals, being 0 values on the left side and 10 on the right side.

Peak Flow Measurements

Oral peak expiratory flow rates were obtained using the Mini-Wright Standard Range Peak Flow Meter and nasal peak flow inspiratory rates were obtained using In-Check Nasal (Clement Clark, Essex, UK).

Table 1 **Population characteristics**

Characteristics	Rhinitis Group	Control Group	*p*
Mean age (yr; SD)	25.9 (5.7)	26.1 (4.7)	0.911*
Gender (% male)	68.9	50.0	0.206#

**The t-test for independent samples.*
#Pearson chi-square test.

Table 2 **Symptoms score and peak flow measurements effects and its recovery time after sudden temperature changes**

Symptoms and Group	Base Mean (SD)	Hot Temperature Mean (SD)	Cold Temperature Mean (SD)	Post Mean (SD)	24 hr Mean (SD)	48 hr Mean (SD)
Nasal blockage						
C	0.8 (1.3)	1.1 (1.6)	1.3 (1.9)	0.9 (1.7)	1.6 (2.6)	1.4 (2.0)
R	4.3 (3.1)	4.0 (2.8)	4.3 (3.0)	4.0 (2.9)	4.9 (2.8)	4.5 (2.7)
Nasal pruritus						
C	1.0 (1.6)	0.5 (0.8)	0.7 (1.4)	0.4 (0.3)	0.4 (0.4)*	0.6 (1.4)
R	3.3 (2.8)	3.4 (2.7)	3.2 (2.8)	3.2 (2.8)	4.0 (3.2)	3.2 (2.8)
Sneezing						
C	0.7 (1.2)	0.5 (0.9)	0.5 (1.0)	0.3 (0.3)	0.7 (0.9)	0.8 (1.5)
R	1.8 (2.5)	2.2 (2.2)	0.9 (6.9)	2.2 (2.6)	2.8 (3.0)*	2.2 (2.6)
Rhinorrea						
C	3.5 (2.1)	2.7 (1.9)	3.5 (2.2)	3.4 (1.9)	3.7 (1.9)	2.7 (2.5)
R	4.4 (2.6)	4.1 (2.3)	4.4 (2.4)	4.2 (2.3)	4.5 (2.7)	4.1 (2.4)
Dry throat						
C	2.0 (2.9)	1.8 (2.7)	2.0 (2.9)	1.9 (3.0)	2.3 (2.5)	0.8 (1.6)
R	3.2 (3.0)	3.2 (2.7)	3.8 (3.2)	3.3 (3.1)	3.6 (3.3)	3.1 (3.2)
Dry mouth						
C	2.5 (3.3)	2.6 (3.2)	2.5 (3.0)	2.5 (0.9)	2.1 (2.8)	0.6 (1.6)*
R	3.3 (3.0)	3.4 (2.9)	3.8 (3.3)	3.4 (3.1)	2.8 (3.2)	2.8 (3.2)
Dry eye						
C	0.6 (0.7)	1.8 (2.2)*	1.3 (2.0)	1.4 (2.5)	0.3 (0.3)	0.7 (1.3)
R	1.8 (2.5)	2.8 (3.0)	2.6 (3.0)	2.7 (2.9)	1.3 (2.1)	1.7 (2.1)
Eye pruritus						
C	0.4 (0.3)	0.7 (1.5)	0.7 (1.6)	0.6 (1.3)	0.3 (0.3)	0.7 (1.7)
R	1.1 (1.7)	2.4 (2.5)**	2.1 (2.3)**	2.0 (2.2)*	1.6 (2.2)	1.8 (2.2)
Eye irritation						
C	0.8 (1.3)	1.1 (1.6)	1.2 (2.2)	0.8 (1.3)	0.5 (0.6)	1.0 (2.2)
R	0.9 (1.4)	2.4 (2.6)**	2.2 (2.5)*	2.4 (2.6)**	1.5 (2.1)	1.6 (2.2)
Breathlessness						
C	0.4 (0.3)	0.6 (1.2)	0.6 (1.0)	0.3 (0.2)	0.3 (0.3)	0.7 (1.3)
R	1.3 (1.7)	2.4 (2.2)**	2.2 (2.3)	2.0 (2.0)	1.8 (2.1)	1.8 (1.8)
Body ache						
C	0.7 (1.3)	0.7 (1.2)	0.8 (1.5)	0.6 (0.8)	1.3 (2.3)	0.7 (0.8)
R	1.0 (1.7)	1.5 (1.8)	1.3 (1.7)	1.3 (1.9)	1.0 (1.7)	1.0 (1.3)
Headache						
C	0.5 (0.4)	1.3 (2.3)	1.7 (2.8)	1.5 (2.6)	0.8 (1.2)	0.9 (1.9)
R	0.8 (1.7)	2.0 (4.2)	2.4 (2.8)*	2.6 (3.0)**	1.2 (1.8)	1.0 (1.7)
Feeling bad						
C	1.1 (1.4)	1.4 (1.7)	1.7 (2.1)	0.8 (0.9)	1.9 (2.4)	0.8 (0.9)
R	1.3 (1.7)	2.0 (2.2)	1.8 (2.1)	1.9 (2.4)*	1.2 (1.6)	1.2 (1.5)
Nasal peak flow						
C	166.6 (90.3)	166.0 (69.5)	166.3 (72.1)	173.7 (69.4)	169.3 (54.2)	183.1 (70.8)
R	142.2 (52.4)	135.5 (58.2)	130.5 (55.9)	146.4 (60.2)	147.5 (62.2)	149.4 (61.5)
Oral peak flow						
C	523.7 (113.8)	521.0 (120.2)	513.0 (134.4)	522.5 (114.3)	500.0 (123.1)	520.6 (120.6)
R	540.8 (107.5)	521.5 (106.0)**	521.8 (104.8)**	519.2 (105.0)**	524.8 (104.1)**	532.8 (112.4)

Hot temperature, 26° C or 78.8° F; cold temperature, 14° C or 57.2° F.
**p < 0.05; **p < 0.01—Wilcoxon test.*
C = control group; R = rhinitis group.

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Statistical Analysis

To compare deviations of the symptoms from the baseline, we used the Wilcoxon nonparametric test. Student's *t*-test and Pearson chi-square test were used to compare the groups' characteristics. Values of $p < 0.05$ were considered significant.

RESULTS

Indoor air pollution levels were considered as low. Mean number (±SD) of viable fungi spores was 117.94 colony-forming units (CFU)/m^3 (±100.5 CFU/m^3), mean carbon dioxide level was 467.8 ppm (±81.6 ppm), and mean concentration of total particulate matter was 6.06 $\mu g/m^3$ (±3.79 $\mu g/m^3$) of air. The absolute humidity was 8.19 g of water vapor per kilograms of dry air ± 0.27 SD for 14°C and 12.87 ± 1.30 for 26°C dry bulb temperature.

No significant difference in population characteristics between the rhinitis and control groups was found (Table 1). The mean scores for symptoms at baseline, cold, and hot temperatures, immediately after and 24 and 48 hours after testing are presented on Table 2.

The rhinitis group reported increased itching and stinging eyes when compared with the baseline during exposure to hot and cold temperatures that lasted until the immediate post-challenge period, but reported no itching and stinging eyes after 24 or 48 hours. The rhinitis group also reported increased breathlessness during hot air exposure. There was a significant decrease in expiratory flow rates in this group during exposure to hot and cold temperatures that persisted 24 hours after challenge. The rhinitis group also reported decreased wellness immediately after challenge and increased sneezing 24 hours after the challenge. This group also reported increased headache during cold air exposure that persisted until immediately after the challenge. After 48 hours, there was no significant difference in any parameters from the baseline. Nasal flow measurements were not different from baseline throughout the experiment in both groups.

The control group reported increased eye dryness at the hot air exposure, decreased nasal pruritus 24 hours after temperature challenge, and decreased mouth dryness 48 hours after the temperature challenge. No difference in nasal flow measurements was observed in this group (Table 2).

DISCUSSION

This study suggests increased susceptibility of individuals with persistent allergic rhinitis to report more respiratory mucosal complaints and decreased forced expiratory flow measurements during and after air-conditioning–induced sudden temperature changes. Self-administered questionnaires can always lead to information bias. Although this visual analog scale is considered complex, mostly because of its bipolarity—symptom's neutrality situated in the middle of the scale—the use of symptoms clearly defined along a continuous line diminishes the information bias (Fig. 1). Although we can not rule out unexpected allergen exposure throughout the entire experiment, pollen exposure in Sao Paulo is clinically irrelevant,[18] and there was no evidence of increased allergen exposure compared with baseline levels throughout the experiment.

To amplify the effects of exposure to moderately cold and moderately hot temperatures, our design aimed at addressing the effects of sudden and consecutive changes of ambient temperature. Although we can not exclude a potential carryover effect, this approach allows us to assess the cumulative effect of temperatures changes, which would have a nonrelevant clinical impact if studied in isolation. The rhinitis group had a significant decrease in oral peak flow measurements during temperature challenges that persisted until 24 hours after the challenge, suggesting that sudden and consecutive temperature changes are a real trigger in developing breathlessness episodes with measurable decrease in pulmonary flow measurements within the susceptible population.

The increase in eye pruritus and irritation in the rhinitis group and eye dryness in the control group can be related to the increase of mucosal symptoms in occupational exposure to lower absolute humidity exposure environments.[19] We did not find increases in reported nose symptoms in either groups during and after challenge (Table 2), despite evidence that nasal challenge with cold, dry air results in release of nasal inflammatory mediators and symptoms as previously established.[20] It is possible that the use of much colder temperatures (×3 to −10°C) and lower relative humidity (<10%) used by Togias *et al.* accounted for the difference. The isolated related increases in reported sneezing in the rhinitis group and the decreased nasal pruritus in the control group 24 hours after the challenge were considered as nonrelated to the challenge *per se* but as caused by intragroup variability.

The increase in headaches reported by the rhinitis group can be related to increased risk of patients with allergies to report headaches and migraines[21] and the cerebral vascular response to temperature changes. The increased headache scores were present only during cold air exposure and immediately after the challenges and did not extend to longer periods.

Taken together, these findings suggest individuals with persistent allergic rhinitis are more prone to develop respiratory and ocular symptoms after exposure to sudden temperature changes. Additional studies with inflammatory mediators are needed to confirm these findings, but protective measures such as adequate clothing and stable indoor temperatures could benefit this subset of the population.

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