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Indoor temperature and humidity in New York City apartments during winter☆

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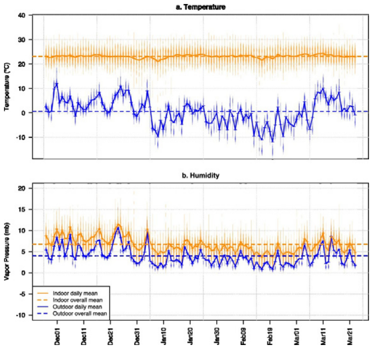
HIGHLIGHTS

- Wintertime air in New York City apartments is very dry.
- Levels of humidity seen here are consistent with increased influenza virus survival.
- Humidifier ownership was not associated with increased indoor humidity.
- Additional research is required to determine how humidifiers can be used effectively.

GRAPHICAL ABSTRACT



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ABSTRACT

Background: Concerns about indoor residential humidity have largely centered on dampness prevention. Overly dry air, however, may favor the survival of some viruses and hence respiratory infections. Many residents employ portable humidifiers to humidify their home environment, yet the effect of these humidifiers on indoor humidity is not known.

Methods: We monitored indoor temperature and humidity in 34 apartments in New York City during winter 2014–2015. We combined information from the monitors with surveyed information on building, household, and apartment-level factors and with information on household humidifier use. Using multilevel regression models, we investigated the role of these factors on indoor absolute humidity levels during the winter.

Results: Mean indoor vapor pressure (a measure of absolute humidity) was 6.7 mb in the surveyed homes during the winter season. Ownership of a humidifier was not associated with higher indoor humidity levels; however, larger building size (above 100 units) was significantly associated with lower humidity. The presence of a radiator heating system was non-significantly associated with higher humidity.

Conclusions: The wintertime indoor environment in this sample of New York City apartments is dry. Future research is needed to evaluate the effectiveness of portable humidifiers in the home and to clarify the relationship between dry indoor air and the transmission of viral infections.

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1. Introduction

Many major cities, including New York City (NYC), regulate a minimum level of heat that must be maintained in multifamily residential buildings during the winter months as a matter of public health policy (NYC Department of Housing Preservation and Development). To our knowledge, no policies exist in any major city to regulate levels of humidity in the winter months. Concerns about humidity in the residential environment have tended to focus on the relationship between high humidity/lack of ventilation and the adverse health consequences of mold proliferation (Arena et al. 2010; Baughman and Arens 1996; Krieger and Higgins 2002; World Health Organization 1990), with much less attention being paid to the health effects of an overly dry environment.

A dry environment, however, may promote the survival and transmission of respiratory viral infections such as influenza, which pose a major health risk during the winter season in temperate parts of the world (Thompson et al. 2003). Low humidity has been associated with influenza infections observationally (Hajat et al. 2004; Mäkinen et al. 2009; Mourtzoukou and Falagas 2007) and via experiments in humans (Johnson and Eccles 2005) and in animals (Lowen et al. 2007; Shaman and Kohn 2009). Humidity affects both the rate of inactivation of the virus and the rates of evaporation and settling of aerosol particles containing the virus (Noti et al. 2013; Yang and Marr 2011), and absolute, rather than relative, humidity seems to be the best environmental predictor of influenza survival and transmission (Shaman et al. 2010; Shaman and Kohn 2009; te Beest et al. 2013; Yaari et al. 2013). A longitudinal study of 30 years of data across 359 urban U.S. counties suggests that approximately half of seasonal mortality from influenza could be attributable to variations in absolute humidity (Barreca and Shimshack 2012).

It is thus possible that the environmental conditions created by residential winter heating without supplemental humidification provide a robust environment for respiratory virus survival, and for the transmission of respiratory infections between susceptible hosts. If this theory holds, humidification of indoor air could reduce disease risk: an experiment in a classroom setting has estimated that 1-h influenza virus survival rates could be reduced from a wintertime maximum of 75% at to about 35–45% via humidification (Koep et al. 2013).

Currently, the amount of measured data about temperature and humidity in the residential environment is very limited (Arena et al. 2010). There are only a few studies that have monitored wintertime temperature and humidity inside homes in the United States (Arena et al. 2010; Nguyen et al. 2013; Tamerius et al. 2013). Particularly, with few exceptions (Myatt et al. 2010) there have been almost no studies that have investigated the effectiveness of attempts to humidify the wintertime residential environment.

Here, we report findings from a study of the temperature and humidity conditions in 34 occupied apartments in New York City over the winter season 2014–2015. The aim of the study is to ascertain the levels of absolute humidity in these homes in the wintertime and to determine the building-level and apartment-level factors that may modify these humidity levels.

2. Methods

2.1. Recruitment and ethical approval

Recruitment for this study was done via email and personal outreach by Columbia's NIEHS Center for Environmental Health in Northern Manhattan and by WeACT for Environmental Justice, an environmental justice organization located in Harlem, NYC. Any household in the boroughs of Manhattan, Brooklyn, and the Bronx was eligible to participate if the head of household was over 18 years of age, the family did not plan to be away from their NYC residence for more than three weeks during the winter, and the main family contact had an active email account. The study protocols and procedures were approved by the Institutional Review Board of Columbia University's Medical Center.

2.2. Indoor temperature and humidity measurements

Indoor temperature and humidity readings were captured using Maxim Integrated DS1923 Hygrochron iButton sensors. These loggers record temperature measurements with an accuracy of ± 0.5 °C within the range of -10 °C–65 °C, and relative humidity (RH) measurements with an accuracy of 0.6% within the range 0–100%. Two to four iButtons were installed in each participant's home, depending on the size of the residence. At a minimum, one sensor was installed in the home's main living room and another in the main bedroom. The sensors were programmed to log measurements every hour, and were attached to walls or furniture at a height of approximately 1.5 m, away from windows and heating devices and out of direct sunlight. The loggers remained in the residences for approximately 5–6 months, at which time they were removed and the data downloaded. These relatively low-cost data loggers cannot be calibrated by the user, but they were purchased immediately prior to study initiation and kept in the field for a maximum of 1 year, reducing the likelihood of sensor drift over time.

2.3. Outdoor temperature and humidity measurements

Hourly outdoor temperature and dew point temperature readings were obtained from the National Oceanic and Atmospheric Association (NOAA) for New York City's Central Park weather station, the closest NOAA weather station to the homes in this study.

2.4. Baseline health and housing information

At an initial home visit, data were collected on variables including: number and ages of household members, approximate hours spent at home, respiratory or cardiovascular diagnoses in the household, number of rooms, bedrooms, and windows in the residence, floor level of residence, type of heating system, humidifier ownership, and building size and age.

2.5. Data analysis

The unit we used for our humidity analyses is vapor pressure (VP), a measure of absolute humidity. Hourly VP levels were calculated from recorded indoor temperature and relative humidity conditions using the Clausius-Clayperon equation (Wallace and Hobbs 2006):

$$e_s(T) = 6.11 \times \exp\left\{5.42 \times 10^3 \times \left(\frac{1}{273} - \frac{1}{T}\right)\right\}; \tag{1}$$

where $e_s(T)$ is the saturation vapor pressure of water at temperature T in degrees Kelvin.

Vapor pressure was calculated as follows:

$$\mathrm{VP} = e_s(T) \times \frac{RH}{100\%} \tag{2}$$

Internal moisture excess refers to the difference between indoor and outdoor humidity (Geving and Holme 2012). We investigated the diurnal patterns of VP by taking the mean of the internal moisture excess by hour of the day.

To test the factors influencing indoor VP, we built multilevel linear regression models with a random intercept to account for the spatial clustering of observations for sensors nested within households. Hourly indoor VP was the dependent variable. Predictors we included in our models a priori were outdoor VP and humidifier ownership.

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