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Evidence from SINPHONIE project: Impact of home environmental exposures on respiratory health among school-age children in Romania

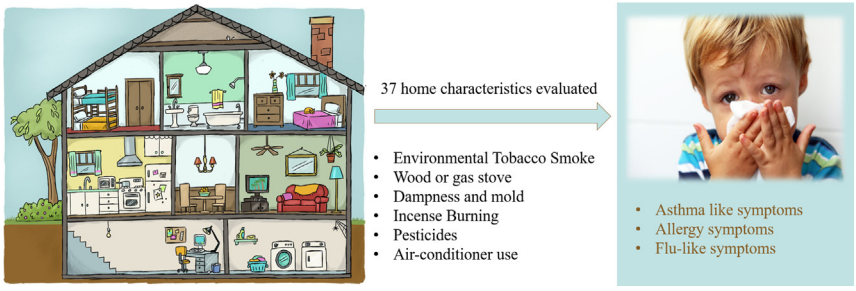
Yi Lu [a], Shao Lin [a,b], Wayne R. Lawrence [b], Ziqiang Lin [a,c], Eugen Gurzau [d,e,f], Eva Csobod [g], Iulia A. Neamtiu [d,e,*]

[a] Department of Environmental Health Science, School of Public Health, University at Albany, State University of New York, 1 University Place, Rensselaer, NY 12144, United States
[b] Department of Epidemiology and Biostatistics, School of Public Health, University at Albany, State University of New York, 1 University Place, Rensselaer, NY 12144, United States
[c] Department of Mathematics and Statistics, College of Arts and Sciences, University at Albany, State University of New York, 1400 Washington Avenue, Albany, NY 12222, United States
[d] Health Department, Environmental Health Center, 58 Busuiocului Street, Cluj-Napoca, Romania
[e] Faculty of Environmental Science and Engineering, Babes-Bolyai University, 30 Fantanele Street, Cluj-Napoca, Romania
[f] Cluj School of Public Health, College of Political, Administrative and Communication Sciences, Babes-Bolyai University, Cluj-Napoca, Romania
[g] Regional Environmental Center for Central and Eastern Europe (REC), Ady Endre ut 9-11, 2000 Szentendre, Hungary

HIGHLIGHTS

- We described the characteristics of Romanian homes and compared them with U.S. homes.
- ETS, dampness/mold, wood/gas stoves use were associated with respiratory symptoms.
- We found a high prevalence of indoor smoking and wide use of wood stove.

GRAPHICAL ABSTRACT



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ABSTRACT

Background: Exposure to indoor air pollutants at home was found to be associated with respiratory diseases. As lifestyle changes with rapid economic growth in Romania, the aim of our study is to describe the characteristics of Romanian homes and their impact on children's respiratory health.
Methods: Self-reported information on respiratory symptoms was collected from 280 Romanian elementary school students in 2011, and the symptoms were categorized into allergy, asthma-like, and flu-like symptoms. Home characteristics and demographic information were collected from questionnaires answered by parents. The association between home characteristics and respiratory health was assessed through multivariate logistic regression controlling for school indoor exposure.
Results: As compared to U.S. households, Romanian homes have a higher percentage of smokers, limited use of indoor climate control, and higher use of iron stoves. Exposure to environmental tobacco smoke was associated with both asthma and allergy symptoms. Additional risk factors identified for allergy symptoms include living in apartments, near pesticide sprayed areas, and the use of incense sticks. The significantly higher risk of flu-like symptoms was associated with mold and dampness issues, the use of air conditioner, gas heater/iron stove in children's bedroom.
Conclusion: Our findings suggest that an increase in respiratory symptoms among Romanian school-age children can be partly related to their environmental exposure at home. Since most of the identified risk factors are preventable, our results provide critical information and evidence for policymakers, to develop target intervention and education strategies.

* Corresponding author at: Environmental Health Center, Busuiocului 58, Cluj Napoca, Romania.
E-mail address: iulianeamtu@ehc.ro (I.A. Neamtiu).

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1. Introduction

School-age children spend on average, more than 16 h a day at home (Wiley et al., 1991). Previous studies have shown that poor housing conditions are associated with poor respiratory health outcomes, especially in children (Breysse et al., 2004; Kanchongkittiphon et al., 2015). Sources of indoor pollutants in homes such as tobacco smoke and unvented gas heater were found to be related to an increase in respiratory symptoms and diseases in children (Li et al., 1999; Pilotto et al., 2004). School-age children who suffer from respiratory diseases are more prone to school absenteeism (Hsu et al., 2016; Simons et al., 2010) and poorer academic performance (Diette et al., 2000; Mendell and Heath, 2005; Vir et al., 1997) and this is often reflected in lower perceived educational attainment and career success (Restuccia and Urrutia, 2004). A report by the World Health Organization (WHO) identified Romania as having one of the highest prevalence of asthma and allergy symptoms among school-age children in the European Region (Wirl and Puklová, 2007). A study conducted in Cluj Napoca, Romania reported that the prevalence of asthma and allergic rhinitis-related symptoms has increased substantially over a six-year period (Chereches-Panta et al., 2011). Nevertheless, except for a few studies on passive smoking (Arghir et al., 2013; Mitchell and Stewart, 2001), there remains no prior research evaluating home environment exposures, as well as the influence of lifestyle and socioeconomic status on student's respiratory health in Romania. Differences in indoor environment and sources of indoor air pollution between developed and developing countries have been shown in previous studies (Bruce et al., 2000; Górny and Dutkiewicz, 2002). Therefore, it is necessary to understand the unique characteristics of homes in Romania before implementing intervention programs and policies that were predominantly designed in developed countries (e.g. Western Europe).

We hypothesize the rapid increase in asthma and allergy symptoms among children in Romania, is partly due to changes in the residential environment. To the best of our knowledge, there are no prior published articles using data from the "Schools Indoor Pollution and Health: Observatory Network in Europe" (SINPHONIE) project to assess the influence of home indoor environment on student's health while controlling for school environment, and fewer studies explored the influence of indoor environment exposures on multiple health symptoms among the Eastern European population. In this study, we intend to (1) describe comprehensive housing characteristics in Romanian homes and compare these characteristics with homes in the U.S. and Western European countries; and (2) assess the association between home exposure and respiratory symptoms (asthma-like symptoms, allergy symptoms, and flu-like symptoms) among school-age children in Romania, controlling for exposure in the school environment.

2. Material and methods

2.1. Overview of SINPHONIE project

SINPHONIE is a Europe-wide *cross sectional* study, funded by European Parliament, focusing on assessing student's exposure to indoor and outdoor air quality in school and other settings, and its impact on student's health. The project was conducted from 2010 to 2012, in 25 European countries (Csobod et al., 2014; Kephalopoulos et al., 2014). Five questionnaire surveys were conducted among school administrators, teachers, students and their parents, to collect information on school environment and policy, home environment, school occupants' health condition, and demographic information. One-time measurement of indoor air pollutant levels including particulate matter with a diameter smaller than 2.5 μm ($PM_{2.5}$), nitrogen dioxide (NO_2), carbon dioxide (CO_2), carbon monoxide (CO), and volatile organic compounds (VOCs) was performed in all participating classrooms. Microclimate conditions (temperature and humidity) and ventilation rate were also measured at the same occasion. This study will only focus on Romanian data collected between October and December in 2011, following the SINPHONIE project protocols.

2.2. Study population

Schools and classrooms in this study were selected following detailed selection criteria (Csobod et al., 2014; Regional Environmental Center, 2014). Five primary schools in Alba County attended by students in grades I to IV were included in the study. In each school, indoor air pollutants and microclimate conditions were monitored in three selected classrooms. A representative sample of classrooms in each school was chosen based on the following selection criteria: (1) classrooms located on different floors and in different areas of the building (towards the street or schoolyard); and (2) occupied by the same class for most of the academic year. Overall, 280 students and their parents agreed to participate in the study and completed the questionnaires, with a response rate of 89.7%.

2.3. Exposure measurement

Information on student's home environment characteristics was gathered from 37 related questions extracted from the self-administered questionnaire answered by their parent(s). Questions asked about housing characteristics including (1) general building information (e.g. construction year, building type); (2) indoor environment characteristics in the dwelling (e.g. heating type, type of cooker); (3) indoor environment characteristics in children's bedroom (e.g. heating type, floor material); (4) exposure to environmental tobacco smoke (ETS); (5) dampness and mold issues; and (6) other environmental concerns (e.g. pets, use of air freshener).

2.4. Outcome measurement

An interview-based survey was conducted with students by a trained interviewer. During the interview, students were asked about whether they ever had an asthma attack and twenty-nine other questions pertaining to health symptoms in the past week, as well as the location where those symptoms occurred (home, school, and other). Survey questions were developed based on standardized questionnaires from the International Study of Asthma and Allergies in Childhood (ISAAC) (Pearce et al., 2007) and the Health Effects of School Environment study (HESE) (Health Effects of School Environment (HESE) Final Scientific Report, 2006). Health symptoms reported by students were categorized into three dichotomous outcomes (see Table A.1): asthma-like symptoms (Yes/No); allergy symptoms (Yes/No); and flu-like symptoms (Yes/No), based on a systematic review (Sá-Sousa et al., 2014) and clinical diagnosis criteria (Quillen and Feller, 2006; Rapid Reference to Influenza Resource Center, 2006). Asthma-like symptoms were defined as either: 1) ever had an asthma attack or wheezing at school, or 2) having any of the following symptoms in the past week: dry cough, difficulty in breathing, wheezing, and difficulty in breathing with wheezing. Fifteen symptoms (e.g. sneezing, skin rash, itching skin or eyes) were defined as allergy-related symptoms and ten symptoms (e.g. running nose, sore throat, fever) were defined as flu-like symptoms.

2.5. Covariates

Demographic and socioeconomic characteristics of households were reported by students' parents and included parental information such as mother's educational levels, employment status, and whether the family received other government benefits (e.g. tax exemptions or government subside for electricity and natural gas). Information on family history of any allergic disorders among core family members (siblings and parents), was also collected. To control for student's exposure to indoor air pollutants at school, CO_2 levels for all 15 classrooms were

measured during the school day (from 8 AM to 1 or until 4 PM, depending on the school schedule) at the same time with the questionnaire survey. A multi-parameter direct reading device (IAQ-Calc model 7545, TSI Inc., Aachen, Germany) was used and the 5 or 8 hour-average (depending on the school program) was calculated. As indicated by a previous study in the U.K. (Chatzidiakou et al., 2015), classroom CO_2 level can serve as a proxy for indoor air quality (IAQ) due to its strong correlation with ventilation rate and some major indoor air pollutants (e.g. PMs and VOCs).

2.6. Statistical analysis

Univariate analyses were conducted for all home characteristics and covariates, and means or medians were reported for continuous variables according to their distributions. Firth's corrected logistic regression, a preferred method for studies with small sample size and separation issues, was used to estimate all odds ratios (ORs) in this study. Adjusted OR (aOR) for each home characteristic was calculated in a single-pollutant model, controlling for potential confounders. Directed Acyclic Graph (DAG) was constructed to identify confounders including student's age, gender, family history of allergic conditions, maternal education, and receiving government benefits. To construct a reduced multi-pollutant model with multiple home exposures, the backward stepwise variable selection and variance inflation factor (VIF) were applied to select important home exposures and control for high collinearity between variables. The final reduced model was constructed including home exposures with $P < 0.25$ and all identified confounders and no VIF of any independent variable exceeded 10. We also conducted a sensitivity analysis where classroom average CO_2 concentration was included as a potential confounder in the final model. Percentage change in OR was calculated to assess the magnitude of the potential confounding related to school indoor environment. All analyzes were conducted using SAS 9.4 (SAS Institute Inc., Cary, NC).

3. Results

3.1. Health condition among students & socio-economic status

Health condition and demographic information of all participants were shown in Tables 1 and A.1. Most participating students were between 8 and 9 years old, and our sample was balanced between genders. Among all participating families, 16% reported at least one direct family member having a family history of allergic conditions. Approximately one-third of the children reported having at least one health symptom in the past week (see Table A.1). The flu-like symptoms were the most common among students, leaded by runny nose (20%), stuffy nose (19%), and sore throat (12%). Consistent with the low prevalence across participating countries in the SINPHONIE study (1.6%) (Csobod et al., 2014), only two students reported that they ever had an asthma attack at school (0.7%) in our study. However, asthma-like symptom such as dry cough was commonly reported among students (20%). Among allergy symptoms, sneeze (11%) is the most common, followed by skin rash (2%) and itchy hands or forearms (2%). When health symptoms were stratified by location of occurrence, the ranks of frequencies of symptoms were similar across different locations. Most of the health symptoms were reported as occurring at home, and happened less often at school or in other locations, such as gyms.

We found that most of the children lived in households with stable financial support and relatively well-educated parents. The employment rate of mothers in our sample was 56%, similar to the 57% reported among all Romanian women (European Platform for Investing in Children, 2016). About 83% of the mothers in the study had a high school or higher degree, while 25% of mothers had a college degree. About 14% of families received state benefits, of which, most reported having disabled and/or unemployed family members.

3.2. Housing characteristics in Romanian homes

As shown in Table 2, most students lived in a house that was constructed after 1970 (with the oldest being built in 1896), and averaged three rooms. Approximately 39% of our participants reported renovating their house within the last 12 months. Soluble and water-resistant paint were commonly used for wall decorations during the renovation. Additionally, most homes were located near some traffic, but only half of the participants reported living within 200 m from heavy traffic (major roads with peak traffic counts >1 car/min). Exposure to ETS at home was very common and at high frequency among the participating students. About 48% of students in our study were exposed to ETS at home, which is much higher than the 17.4%–25% reported in U.S. homes (Centers for Disease Control and Prevention, 2007; Sobotova et al., 2011). Visible mold issue was more common somewhere else in the house (18%) than in children's bedroom (6%). Low use of indoor environment control tools such as air conditioner (AC) (6%), mechanical ventilation (8%), and humidifier (13%) was reported, as compared to

Table 1
Description of students' demographic status.

Variable	N (%)	Asthma like symptoms (n = 55)	Allergy symptoms (n = 49)	Flu-like symptoms (n = 85)
Gender				
Female	141 (50.36)	Ref	Ref	Ref
Male	139 (49.64)	0.89 (0.49, 1.60)	0.82 (0.43, 1.56)	0.78 (0.47, 1.30)
Age (years)[a]				
6-7	31 (11.07)	0.91 (0.67, 1.23)	1.11 (0.80, 1.54)	1.13 (0.88, 1.47)
8-9	188 (67.14)			
10-11	61 (21.79)			
Mother's education				
Primary school or less	47 (16.79)	1.08 (0.38, 2.98)	1.22 (0.42, 3.43)	0.48 (0.19, 1.11)
Secondary school	71 (25.36)	1.61 (0.68, 3.90)	1.66 (0.69, 4.17)	0.88 (0.44, 1.77)
Vocational school	80 (28.57)	2.12 (0.95, 4.96)	1.43 (0.60, 3.59)	1.11 (0.57, 2.17)
College	71 (25.36)	Ref	Ref	Ref
Missing	11 (3.93)	–	–	–
Mother's employment				
Full-time employee	158 (56.43)	Ref	Ref	Ref
Part time/unemployed/disabled/pensioner	73 (26.07)	1.07 (0.53, 2.10)	1.12 (0.52, 2.32)	0.91 (0.50, 1.64)
Missing	49 (17.50)			
Receiving state benefit	39 (13.93)	1.34 (0.58, 2.90)	1.49 (0.61, 3.32)	0.76 (0.34, 1.58)
Family history of any allergic conditions	44 (15.71)	0.42 (0.13, 1.06)	1.16 (0.46, 2.65)	1.40 (0.71, 2.73)
	Mean (ppm)			
Classroom CO_2 level[a]	1995	0.96 (0.90, 1.03)	1.01 (0.94, 1.09)	0.98 (0.92, 1.04)

[a] Age and classroom average CO_2 level (per 100 ppm increase) were included as continuous variable when calculating their crude ORs.

Table 2
Description of home exposures and their association with health outcomes among students in single-pollutant model.
The bolded OR in the table represents an estimated OR with a corresponding p-value less than 0.05.

Home characteristics	N (%)	Adjusted OR[a] in single-pollutant model (95%CI)		
		Asthma-like symptoms	Allergy symptoms	Flu-like symptoms
Building general information				
Housing type				
Single family house	163 (60.59)	Ref	Ref	Ref
Apartment	78 (29.00)	1.30 (0.65, 2.57)	2.08 (1.02, 4.21)	1.05 (0.57, 1.90)
Semi-detached house/other	28 (10.41)	0.90 (0.26, 2.55)	0.36 (0.04, 1.54)	0.52 (0.17, 1.37)
Location to traffic				
Away from traffic	49 (18.01)	Ref	Ref	Ref
Near heavy or light traffic	223 (81.99)	1.02 (0.46, 2.49)	0.56 (0.26, 1.30)	0.88 (0.45, 1.80)
<200 m from heavy traffic				
No	131 (48.88)	Ref	Ref	Ref
Yes	137 (51.12)	**0.45 (0.23, 0.86)**	0.91 (0.46, 1.81)	0.62 (0.36, 1.09)
	Median			
# of rooms	3	0.95 (0.72, 1.23)	0.78 (0.55, 1.07)	1.03 (0.83, 1.29)
# of people in dwelling	4	0.93 (0.72, 1.21)	1.02 (0.80, 1.29)	1.01 (0.83, 1.23)
Construction year	1979	Not calculated	Not calculated	Not calculated
Renovated in 12 months				
No	168 (61.31)	Ref	Ref	Ref
Yes	106 (38.69)	1.02 (0.53, 1.94)	0.86 (0.42, 1.73)	0.98 (0.55, 1.71)
Indoor environmental characteristics in dwelling				
Fireplaces				
No	207 (76.38)	Ref	Ref	Ref
Yes	64 (23.62)	1.46 (0.71, 2.91)	0.97 (0.42, 2.10)	0.88 (0.46, 1.64)
Mechanical ventilation				
No	247 (92.16)	Ref	Ref	Ref
Yes	21 (7.84)	1.19 (0.35, 3.40)	1.46 (0.42, 4.20)	1.73 (0.67, 4.32)
Air conditioner				
No	255 (93.75)	Ref	Ref	Ref
Yes	17 (6.25)	1.53 (0.44, 4.48)	1.47 (0.37, 4.60)	2.21 (0.80, 6.03)
Humidifier				
No	232 (86.89)	Ref	Ref	Ref
Yes	35 (13.11)	0.80 (0.27, 2.01)	0.78 (0.24, 2.09)	0.87 (0.38, 1.88)
Gas heater				
No	88 (33.59)	Ref	Ref	Ref
Yes	174 (66.41)	1.07 (0.53, 2.26)	**0.35 (0.16, 0.76)**	0.85 (0.46, 1.60)
Type of cooker in kitchen				
Coal/wood fired oven	11 (4.01)	0.86 (0.09, 4.53)	1.91 (0.31, 8.81)	0.68 (0.07, 3.51)
Gas/electronic cooker	263 (95.99)	Ref	Ref	Ref
Functioning extractor fan above cooker				
No	102 (37.50)	Ref	Ref	Ref
Yes	170 (62.50)	0.90 (0.47, 1.77)	0.94 (0.46, 1.99)	1.63 (0.90, 3.01)
Gas boiler in bathroom				
No	248 (93.58)	Ref	Ref	Ref
Yes	17 (6.42)	2.07 (0.66, 5.86)	0.78 (0.15, 2.70)	1.41 (0.48, 3.80)
Exists garage communicating with dwelling				
No	249 (91.54)	Ref	Ref	Ref
Yes	23 (8.46)	1.43 (0.41, 4.19)	1.83 (0.53, 5.34)	1.41 (0.51, 3.70)
Indoor environmental characteristic in children's bedroom				
Air conditioner				
No	267 (97.80)	Ref	Ref	Ref
Yes	6 (2.20)	0.38 (0.00, 3.62)	0.49 (0.00, 4.71)	2.07 (0.32, 11.11)
Bedroom floor material				
Linoleum/plastic/tile	18 (6.50)	0.13 (0.00, 1.09)	0.81 (0.15, 3.12)	0.65 (0.15, 2.18)
Wall to wall carpet	57 (20.58)	0.85 (0.36, 1.84)	0.74 (0.27, 1.77)	1.03 (0.51, 2.03)
Wood/parquet	202 (72.92)	Ref	Ref	Ref
Carpets				
No	24 (8.89)	Ref	Ref	Ref
Yes	246 (91.11)	1.26 (0.42, 4.94)	1.13 (0.38, 4.45)	1.24 (0.49, 3.50)
Heating type				
Electric/radiator/floor heating	35 (12.96)	Ref	Ref	Ref
Gas heater/gas stove	161 (59.63)	1.09 (0.41, 3.29)	2.17 (0.64, 11.23)	1.76 (0.69, 5.23)
Tiled clay/iron stove	74 (27.41)	1.19 (0.41, 3.88)	2.23 (0.61, 11.95)	2.13 (0.77, 6.72)
Environmental tobacco smoke				
Frequency of children's exposure to ETS				
Never	167 (61.17)	Ref	Ref	Ref
Daily	30 (10.99)	**2.87 (1.09, 7.32)**	**5.18 (1.95, 13.71)**	1.32 (0.53, 3.18)
Often	40 (14.65)	1.90 (0.77, 4.53)	1.98 (0.69, 5.35)	1.32 (0.58, 2.92)
Sometimes	36 (13.19)	1.68 (0.64, 4.13)	2.51 (0.90, 6.57)	1.30 (0.57, 2.84)
# of cigarettes per day				
None	175 (63.87)			
1–2 cigarettes/day	22 (8.03)	**5.00 (1.86, 13.28)**	1.69 (0.41, 5.42)	**3.07 (1.23, 7.82)**
3–4 cigarettes/day	29 (10.58)	1.67 (0.57, 4.39)	**3.83 (1.34, 10.50)**	2.08 (0.87, 4.91)

Table 2 (*continued*)

Home characteristics	N (%)	Adjusted OR[a] in single-pollutant model (95%CI)		
		Asthma-like symptoms	Allergy symptoms	Flu-like symptoms
5–10 cigarettes/day	30 (10.95)	2.52 (0.95, 6.39)	**5.07 (1.96, 13.04)**	0.80 (0.29, 2.00)
>10 cigarettes/day	18 (6.57)	2.58 (0.69, 8.57)	**3.96 (1.02, 13.71)**	1.40 (0.38, 4.46)
# of smokers in dwelling	Mean 0.66	**1.62 (1.10, 2.39)**	**1.86 (1.23, 2.82)**	1.35 (0.96, 1.90)
Dampness and mold				
Visible mold/water leakage in past 12 months				
No	216 (81.82)	Ref	Ref	Ref
Yes	48 (18.18)	0.74 (0.27, 1.75)	**0.30 (0.06, 0.95)**	**2.09 (1.04, 4.20)**
Condensation on windows in winter				
No	193 (71.22)	Ref	Ref	Ref
Yes	78 (28.78)	0.90 (0.42, 1.83)	1.47 (0.69, 3.04)	1.70 (0.94, 3.08)
Dampness/visible mold in children's bedroom				
No	258 (93.82)	Ref	Ref	Ref
Yes	17 (6.18)	0.99 (0.18, 3.74)	0.56 (0.06, 2.51)	**4.72 (1.55, 15.71)**
Dampness/mold issue in past 5 years				
No	223 (81.68)	Ref	Ref	Ref
Yes	50 (18.32)	0.80 (0.30, 1.88)	0.91 (0.33, 2.18)	1.91 (0.95, 3.81)
Allergen and chemical products				
Pets				
No	240 (87.91)	Ref	Ref	Ref
Yes	33 (12.09)	1.16 (0.42, 2.82)	**0.25 (0.03, 0.99)**	1.04 (0.43, 2.34)
Seen cockroaches in the house				
Never	220 (80.29)	Ref	Ref	Ref
Rarely	34 (12.41)	0.92 (0.34, 2.22)	1.54 (0.59, 3.64)	1.26 (0.56, 2.71)
Sometimes	20 (7.30)	0.51 (0.10, 1.78)	1.38 (0.34, 4.43)	1.19 (0.40, 3.26)
House is located near area sprayed with pesticides				
No	201 (74.44)	Ref	Ref	Ref
Yes	69 (25.56)	1.11 (0.51, 2.29)	1.47 (0.66, 3.12)	1.06 (0.55, 2.00)
Use of air fresheners				
No	126 (46.67)	Ref	Ref	Ref
Yes	144 (53.33)	0.87 (0.46, 1.68)	1.62 (0.80, 3.39)	1.03 (0.59, 1.79)
Use of incense sticks				
No	240 (87.91)	Ref	Ref	Ref
Yes	33 (12.09)	1.51 (0.61, 3.45)	2.06 (0.83, 4.72)	**2.13 (1.00, 4.49)**
Use of glues solvents & industrial products				
No	260 (95.94)	Ref	Ref	Ref
Yes	11 (4.06)	0.89 (0.16, 3.58)	3.88 (0.95, 14.84)	1.01 (0.23, 3.78)

[a] Adjusted for age, gender, family history of allergic conditions, maternal education, receiving state benefit or not.

the U.S. homes, where 87% of them own AC system (U.S. Energy Information Administration, 2011). Heating appliances with higher emissions of indoor pollutants such as gas heaters (66%) and tile clay or iron stoves (27%) were widely used in participating households. Higher use of coal or wood for cooking was also reported in Romanian homes (4.1%) compared to U.S. homes (2.1%) (U.S. Energy Information Administration, 2014). Wood flooring was used in the majority of Romanian households compared to the higher use of wall-to-wall carpet in the U.S. home (Crain et al., 2002). Noteworthy, for 91% of the households was reported the use of carpets in children's bedroom, which can serve as a reservoir of VOCs and indoor allergens. Pets are less common in Romanian families (12%) compared to U.S. families (56%), indicating less exposure to pets' fur, a known allergen (American Humane Association, 2012). However, cockroach, a known source of allergen that triggers allergic sensitization, was reported in 20% of the households. Air fresheners were used in half of the households, a slightly lower rate compared to U.S. homes (75%) (National Resources Defence Council, 2007), while incense stick use seems to be more common in Romanian homes (12%).

3.3. Association between home characteristics and student's asthma-like symptoms

Exposure to ETS at home was strongly associated with asthma-like symptoms. Asthma-like symptoms were significantly associated with all three ETS exposure indicators (frequency of exposure, the number of smokers, and the number of cigarettes smoked per day), in the single-pollutant model with estimated ORs range from 1.62 to 5.00 (Table 2). We also saw a possible dose-response effect when using frequency of exposure. Daily exposure was associated with the highest risk (aOR = 2.87, 95%CI: 1.09, 7.32) followed by "often" exposure category (aOR = 1.90, 95%CI: 0.77, 4.53), and then "sometimes" exposure category (OR = 1.68, 95%CI: 0.64, 4.13) (Table 2). Surprisingly, living within 200 m of traffic was associated with reduced asthma-like symptoms (aOR = 0.45, 95%CI: 0.23, 0.86).

After backward selection, six home characteristics were maintained in the final reduced model (Table 3.1). The number of cigarettes smoked per day was chosen in the reduced model as a representative for ETS exposure. Smoking 1–2 cigarette(s) per day (aOR = 5.13, 95%CI: 1.84, 14.28) was significantly associated with asthma-like symptoms among children, while other categories were marginally significant. In the sensitivity analysis, these significant associations were also observed. The changes in estimated aORs for exposures were relatively small after controlling for classroom average CO_2 level (0%–10%) (data not shown).

3.4. Association between home characteristics and student's allergy symptoms

In the single-pollutant model, exposure to ETS and housing type were associated with an increased risk of allergy symptoms among children. Similar to the results for asthma-like symptoms, the ETS exposure indicators were also significantly associated with 1.7 to 5.2-fold increased risk of allergy symptoms (Table 2). However, a dose-response effect was not seen. A two-fold increased risk of allergy symptoms was also shown among children living in an apartment as compared

Table 3.1
Adjusted ORs of association between selected home exposures and student's self-reported asthma-like symptoms in the multi-pollutant model (N = 231).
The bolded OR in the table represents an estimated OR with a corresponding p-value less than 0.05.

Home characteristics	Adjusted OR[a] (95%CI)	
	Final reduced model	Final reduced model control for classroom CO_2 level
Housing type		
Single family house	Ref	Ref
Apartment	1.49 (0.68, 3.26)	1.46 (0.66, 3.19)
Semi-detached house/others	0.30 (0.05, 1.22)	0.31 (0.05, 1.28)
# of cigarettes smoked per day		
None	Ref	Ref
1–2 cigarettes/day	**5.13 (1.84, 14.28)**	**4.89 (1.74, 13.75)**
3–4 cigarettes/day	2.48 (0.79, 7.25)	2.65 (0.84, 7.79)
5–10 cigarettes/day	2.42 (0.82, 6.74)	2.39 (0.81, 6.69)
>10 cigarettes/day	3.47 (0.86, 12.86)	3.81 (0.93, 14.53)
# of rooms	1.23 (0.84, 1.80)	1.20 (0.82, 1.77)
Having gas boiler in the bathroom	2.55 (0.70, 8.78)	2.62 (0.72, 8.93)
Having carpet in children's bedroom	1.53 (0.46, 6.60)	1.65 (0.49, 7.18)
Reported visible mold/water leakage in past 12 months	0.58 (0.20, 1.46)	0.58 (0.20, 1.47)

[a] Both models adjusted for age, gender, family history of allergic conditions, maternal education, receiving state benefit or not.

to a single house. Using a gas heater in the house was negatively related to allergy symptoms among children (aOR = 0.35, 95%CI: 0.16, 0.76).

Eleven home characteristics were included in the final reduced model (Table 3.2). Consistent with the single-pollutant model, the number of cigarettes smoked per day and housing type were positively associated with allergy symptoms. An increased risk of allergy symptoms was also shown among families that used incense stick frequently and for the households near an area where pesticides are sprayed. Pets' ownership was positively related to the risk of allergy symptoms, but with wide confidence interval. Surprisingly, visible mold or water leakage in the house was associated with a reduced risk of allergy symptoms among children (aOR = 0.1, 95%CI: 0.01–0.44).

3.5. Association between home characteristics and student's flu-like symptoms

Increased risk of flu-like symptoms was observed among children living in the households with reported dampness and mold issues, in the single-pollutant model. Among the four indicators of dampness and mold issues, both mold growth/water leakage in the past 12 months (aOR = 2.09, 95%CI: 1.04, 4.20) and mold/dampness issues in child's bedroom (aOR = 4.72, 95%CI: 1.55, 15.71) were significantly associated with flu-like symptoms, while another two indicators were marginally significant (Table 2). Flu-like symptoms were also more common among children who lived in households with a smoker who smoked 1–2 cigarette(s) per day (aOR = 3.07, 95%CI: 1.23, 7.82) or households with frequent use of incense stick (aOR = 2.13, 95%CI: 1.00, 4.49).

In the final model, seven home characteristics were selected (Table 3.3). As expected, elevated risk of flu-like symptoms was associated with mold/dampness issues in child's bedroom, with a similar magnitude of the effect. Type of heating used in child's bedroom was another important risk factor for flu-like symptoms. Elevated risks of flu-like symptoms were seen among families using tile clay/iron stove (aOR = 4.80, 95%CI: 1.44, 20.13) and families using gas heater/gas stove (aOR = 3.92, 95%CI: 1.26, 15.62), as compared to families using electric/radiator heater. AC use in the house was also associated with a 4.2 times higher risk of flu-like symptoms. After including multiple home characteristics, the association between the number of cigarettes smoked per day and flu-like symptoms was attenuated and marginally significant. Consistent results were shown in the sensitivity analysis.

Table 3.2
Adjusted ORs of association between selected home exposure and student's self-reported allergy symptoms in the multi-pollutant model (N = 230).
The bolded OR in the table represents an estimated OR with a corresponding p-value less than 0.05.

Home characteristics	Adjusted OR[a] (95%CI)	
	Final reduced model	Final reduced model control for classroom CO_2 level
Housing type		
Single family house	Ref	Ref
Apartment	**3.32 (1.32, 8.91)**	**3.56 (1.37, 10.10)**
Semi-detached house/others	0.41 (0.04, 2.01)	0.44 (0.04, 2.22)
# of cigarettes smoked per day		
None	Ref	Ref
1–2 cigarettes/day	2.24 (0.45, 9.25)	1.89 (0.37, 8.03)
3–4 cigarettes/day	**12.25 (3.02, 56.20)**	**12.94 (3.11, 62.00)**
5–10 cigarettes/day	**7.92 (2.16, 31.12)**	**8.24 (2.26, 32.41)**
>10 cigarettes/day	3.89 (0.70, 21.28)	3.97 (0.70, 22.83)
Children's bedroom floor material		
Wood/parquet	Ref	Ref
Linoleum/plastic/tile	0.36 (0.02, 3.20)	0.27 (0.01, 2.48)
Wall-to-wall carpet	1.56 (0.41, 5.55)	1.55 (0.42, 5.35)
Children's bedroom heating type		
Electric/radiator/floor heating	Ref	Ref
Gas heater/gas stove	3.29 (0.61, 40.39)	2.65 (0.50, 29.53)
Tiled clay/iron stove	2.50 (0.41, 32.23)	2.91 (0.49, 33.97)
Having gas boiler in the bathroom	0.70 (0.09, 3.79)	0.73 (0.10, 3.92)
Having pets in the dwelling	**24.81 (3.25, 396.50)**	**29.70 (3.76, 541.11)**
Reported mold/water leakage in past 12 months	**0.10 (0.01, 0.44)**	**0.09 (0.01, 0.40)**
Reported dampness/condensation on windows in winter	1.81 (0.64, 4.99)	1.96 (0.69, 5.51)
Frequent use of air fresheners	0.68 (0.28, 1.62)	0.61 (0.24, 1.48)
Frequent use of incense stick	**3.25 (1.03, 10.26)**	**4.66 (1.37, 16.52)**
Close to cultivation sprayed by pesticides	**3.53 (1.27, 10.29)**	**4.17 (1.43, 13.26)**

[a] Both models adjusted for age, gender, family history of allergic conditions, maternal education, receiving state benefit or not.

4. Discussion

In this study, we provided an overview of comprehensive housing characteristics in Romanian homes, which were unique as compared to the U.S. or Western European countries. Indoor smoking was very common in Romanian homes and served as an important risk factor for triggering asthma and allergy-related symptoms, and was marginally significant for flu-like symptoms among children in Romania. Sources of VOCs such as pesticide and incense sticks use were found to be contributing factors to allergy related symptoms among children. Dampness/mold were the strongest risk factors related to flu-like symptoms, followed by iron or gas stove use and AC use.

4.1. Characteristics of Romanian homes

When compared to the U.S. and Western European countries, Romanian homes face unique challenges. Exposure to ETS was one of the most common health risk factor identified in Romanian homes. Children were also exposed to a very high level of ETS at home, since 50% of the smokers in our study reported consuming more than five cigarettes per day (data not shown). Romanian homes may also have higher levels of pollutants such as PMs and NO_2 related to indoor combustion due to the higher prevalence of gas heaters and solid fuel use. While having extractor fans in the house may help, 88% of fans in Romanian homes did not have an outlet outdoors, which indicated poor emission control. Less indoor climate control was used in Romanian homes compared to developed countries, indicating less control over indoor temperature and humidity. This may pose a challenge in managing dampness and mold issues, which were common among participating families. Unlike homes in developed countries, Romanian homes were

Table 3.3
Adjusted ORs of association between selected home exposure and student's self-reported flu-like symptoms in the multi-pollutant model (N = 242).
The bolded OR in the table represents an estimated OR with a corresponding p-value less than 0.05.

Home characteristics	Adjusted OR[a] (95%CI)	
	Final reduced model	Final reduced model control for classroom CO_2 level
# of cigarettes smoked/day		
None	Ref	Ref
1–2 cigarettes/day	2.45 (0.88, 6.87)	2.43 (0.87, 6.84)
3–4 cigarettes/day	1.99 (0.76, 5.15)	1.99 (0.76, 5.16)
5–10 cigarettes/day	0.94 (0.32, 2.47)	0.93 (0.32, 2.44)
>10 cigarettes/day	1.84 (0.48, 6.37)	1.91 (0.49, 6.70)
Children's bedroom heating type		
Electric/radiator/floor heating	Ref	Ref
Gas heater/gas stove	**3.92 (1.26, 15.62)**	**3.73 (1.20, 14.95)**
Tiled clay/iron stove	**4.80 (1.44, 20.13)**	**4.92 (1.48, 20.71)**
Having air conditioner in the dwelling	**4.21 (1.34, 13.97)**	**3.85 (1.22, 12.80)**
Having functioning extractor fan above cooker	1.76 (0.92, 3.48)	1.77 (0.93, 3.50)
Dwelling renovated in the past 12 months	0.82 (0.44, 1.51)	0.87 (0.46, 1.62)
Reported dampness/condensation on windows in winter	1.73 (0.90, 3.31)	1.81 (0.94, 3.51)
Reported dampness/visible mold in children's bedroom	**4.23 (1.21, 16.78)**	**3.89 (1.10, 15.56)**

[a] Both models adjusted for age, gender, family history of allergic conditions, maternal education, receiving state benefit or not.

less prone to the allergen from pets, but more from pests. As compared to the U.S., where air fresheners and wall-to-wall carpet served as important emission sources and reservoir for VOCs, Romanian homes were more likely to have VOCs emitted from incense sticks burning and pesticide spray nearby.

4.2. Environmental tobacco smoke

Exposure to ETS was consistently shown to be the strongest risk factor for both asthma-like and allergy symptoms in the current study. Smoking indoors is a major source of multiple indoor air pollutants including PMs, VOCs, and heavy metals like cadmium. Toxicological experiments have shown that exposure to cigarette smoke can reduce lung function and increase IgE levels in both laboratory animals and humans (Ferrante et al., 2014). Our study observed stronger effects as compared to pooled estimates in a recent review, where passive smoking inside households was associated with the incidence of wheezing (pooled OR = 1.32) and incidence of asthma (pooled OR = 1.30) among children ages 5–18 years (Randolph, 2012). This difference may be partly explained by the larger percentage of children exposed to ETS more frequently and at a higher level, in our study. Romanian children are also more likely to be exposed to ETS in other public places. Although Romania banned smoking in most indoor public/work spaces (e.g. school, theaters, and restaurants) by 2015, lower public support was reported among Romanians as compared to other Eastern European countries (Muilenburg et al., 2010). Moreover, even though mothers in our sample were overall well-educated, the prevalence of exposure to ETS in households observed in our study (39%) was higher than the prevalence of smoking among Romanian adults reported by the European Commission Eurobarometer survey (31%) in 2006 (Bogdanovica et al., 2011). In summary, exposure to ETS may pose a substantial health risk to school-age children in Romania, due to its high prevalence.

4.3. Moisture and mold

Our study also indicated a four-fold increase in the risk of flu-like symptoms among school-age children due to dampness/mold issue in their bedroom, after controlling for exposure to ETS. Similar findings were reported by LARES study where visible mold in the house was associated with cold among children (OR = 1.4, 95%CI: 1.2, 1.7) (World Health Organization Regional Office for Europe, 2007). Although no direct measurement of mold was taken in our study, a significant association between self-reported visible mold and mold detected in air samples was reported in previous studies (Polyzois et al., 2014). The potential mechanisms suggested by previous experimental studies include: 1) specific microorganisms can lead to airway inflammation and immunosuppressive reaction and, 2) the dampness in the house can result in the excess emission of irritating air pollutants from building materials (e.g. formaldehyde) (Fisk et al., 2010). Although Romania has a moderate precipitation (637 mm per year), dampness and mold issues were more common in Romanian homes than in U.S. homes (American Housing Survey for the United States: 2009, 2011), or other nearby European countries (World Health Organization Regional Office for Europe, 2007). While use of mechanical ventilation was rare in Romanian homes, increasing frequency of natural ventilation and cleaning may help reduce the indoor humidity and prevent mold growth.

4.4. Indoor VOCs sources

We found that children living in homes where incense sticks were frequently used had a 3-fold increased risk of allergy symptoms. One study conducted among Taiwanese school-age children also found a significant association between incense sticks burning at home and coughing, but not with asthma or allergic rhinitis (Yang et al., 1997). However, there were conflicting results regarding the health impact of incense sticks use, since no harmful health effects were shown in two other studies conducted among school-age children (Koo et al., 1995; Lee et al., 2003). This may be partly explained by the diverse chemical compositions of incense sticks smoke. While burning of incense sticks generally leads to the emission of particulate matters, the emission of VOCs varies among incense sticks made of different materials or used for different purposes (Manoukian et al., 2013).

Living near a pesticide sprayed area, a potential outdoor source of VOCs, was also associated with a 3.5-fold increased risk of allergy symptoms among children. Since our study had a good mixture of households from rural and urban areas, the pesticide sprayed areas consisted of both farm and non-farm setting. While most studies focused on pesticide exposure in an occupational setting or agriculture community, there is an increasing body of literature that associates chronic residential exposure to pesticides with respiratory symptoms among children (Eskenazi et al., 1999; Salam et al., 2003; Salameh et al., 2003). Children are more vulnerable and more likely to be exposed to higher level of pesticide compared to adults, due to their hand-to-mouth behavior and fast metabolism (Salam et al., 2003).

4.5. Indoor environment control

The use of AC in the house was associated with a 4.2-fold increased risk of flu-like symptoms. This finding is consistent with a 4.1-fold increased risk of influenza-like illness due to AC use reported in a study conducted in Brazil (Silva et al., 2014). The use of AC can help create an environment with low humidity, which helps airborne microorganisms to survive and transmit. Furthermore, microorganisms that are allergens or pathogenic have been found to grow on AC filters, which were rarely changed or cleaned in homes (Ager and Tickner, 1983).

Children with gas heaters or iron stoves in their bedrooms had 4 times and 5 times higher risk of flu-like symptoms, respectively, compared to other heating systems. Low efficient heating systems, especially when using wood or coal, were well documented as indoor sources of

PMs, NO_2, and SO_2 (Bernstein et al., 2008). One study conducted in inner-city homes in Baltimore, showed a strong association between indoor NO_2 level and gas heater/heating stove use, after adjusting for other home characteristics (Hansel et al., 2008). A community randomized trial in New Zealand also found that when replaced with a non-polluting and efficient heating system, lower respiratory tract symptoms in children were significantly reduced (Howden-Chapman et al., 2008).

Unexpectedly, a negative relationship was found between the use of the gas heater in the dwelling and allergy symptoms. A possible explanation was that tile clay/iron stoves were more common in child's bedroom in households that did not have gas heaters (64%), compared to those with gas heaters (10%).

4.6. Housing type and location

After adjusting for socioeconomic factors, children living in an apartment still had a significantly higher risk of allergy symptoms compared to children living in a single house. As shown in LARES report, housing type may be associated with a wide range of factors such as ownership (owner/rental), building age and style (e.g. size of the window), ventilation system (natural/mechanical), infestation, and cleaning practices (e.g. centralized garbage storage) (World Health Organization Regional Office for Europe, 2007). While housing type may have limited impact on IAQ directly, it might have a large indirect effect on IAQ through the factors mentioned above.

Unexpectedly, living within 200 m of heavy traffic was associated with lower risk of asthma-like symptoms. One possible explanation was that this variable was not a good indicator for household proximity to traffic. When we compared this variable with the other variable on household proximity to traffic (house location towards the traffic), little agreement was found between these two variables. Half of the people who reported to live within 200 m of heavy traffic chose the option of "lived near light traffic", and another 9% of them chose the option "live away from traffic" in the other question. The association between the variable house location towards the traffic and asthma-like symptoms was not protective, with an estimated OR of 1.02.

4.7. Strengths and limitations

To our knowledge, this is the first study focusing on the association between a wide variety of home characteristics and children's respiratory health in Romania. Based on data collected by the SINPHONIE project, we evaluated multiple home characteristics in the same model and adjusted for important confounders such as socioeconomic status and family disease history. Using the information on both school and home environment collected simultaneously, we were able to adjust for potential confounding due to school environment exposure, to improve the study validity. In contrast with most of the previous studies, which only focused on one specific disease, we evaluated the impact of home environment on multiple outcomes, including asthma-like, allergy, and flu-like symptoms.

One concern in our study was the accuracy of our outcome definition. As discussed by Sá-Sousa et al., there was no unified definition of asthma in the current literature (Sá-Sousa et al., 2014). According to a national survey in 2013, the prevalence of asthma among Romanians varied widely when defined by symptoms instead of doctor diagnosis, which indicated a severe under-diagnosis of asthma and allergy (Bumbacea et al., 2013). Therefore, we decided to define our outcome on related health symptoms instead of doctor diagnosis, to secure the sensitivity and statistical power in this study. Additionally, due to limited knowledge and attention to personal health, health symptoms could be underreported by students as compared to parents' observation. However, self-reported symptoms by students were also more likely to capture symptoms that occurred in locations outside the house, and less biased by the relationship between children and parents. This also reduced the potential reporting bias, since we collected our exposure and outcomes data from two different sources. In our future study, we also plan to assess the consistency between symptoms reported by student or parent and student's spirometry test result.

Another concern was the limited statistical power and considerable uncertainty in our study. Although we had a moderate sample size, some of the estimates had wide confidence intervals due to uncommon home characteristics (e.g. pets in the dwelling) or strata (e.g. smoke >10 cigarettes/day). To improve precision, we combined strata that may have a similar effect (e.g. floor heating and radiator) and used Firth's logistic regression model to calculate ORs. We kept more detailed strata for important factors such as smoking, to assess the potential dose-response effect. Our estimates were also less vulnerable to bias due to missing values since only two variables included had >5% missing.

The final limitation was the cross-sectional design of the SINPHONIE project. Because of the absence of temporality, our findings should be interpreted with caution and cannot indicate a causal relationship. However, this cross-sectional study was based on high-quality data and valid design, and can be very helpful by providing baseline knowledge for future research and policy development. Home characteristics were reported by parents which are considered to be a reliable source of information for the indoor environment studies (Naydenov et al., 2008). Also, multiple important confounders such as family socioeconomic status, history of allergy, and school environment were controlled for in the analysis. As there was no other comprehensive survey of home characteristics conducted in Romania, our study may be the first to provide an overview of home characteristics that may be associated with potential health risks for the occupants. Although housing characteristics were unlikely to cause health effect on their own, they provide valuable information for future development of effective intervention strategies.

5. Conclusion

For Romanian homes, we reported a higher frequency of indoor smoking, more common use of gas heater and iron stove, and low use of mechanical ventilation and AC. In our study, exposure to ETS at home was found to be strongly associated with elevated risk of self-reported asthma-like and allergy symptoms among school-age children. Other factors that were associated with allergy symptoms in children included house-building type, use of incense stick, and living near a pesticide sprayed area. Potential risk factors for flu-like symptoms were dampness and mold issues, type of heating, use of AC, and use of incense sticks. Most of the home characteristics identified in this study are easy to remediate and can be used as indicators for developing specific intervention programs such as education programs to reduce indoor smoking and increase natural/mechanical ventilation.

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Appendix A

Table A.1
Definition of self-reported health outcomes and break-down of outcomes by occurrence location.

	Any location	Home	School	Other
	N (%)	N (%)	N (%)	N (%)
Asthma like symptoms				
Ever had an asthma attack (or wheezing or whistling in the chest) while at school?	2 (0.7)		2 (0.7)	
Dry cough	55 (19.6)	54 (19.3)	32 (11.4)	0 (0.0)
Difficult breathing	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Wheezing in the chest	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Difficult breathing with wheezing in the chest	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Allergy symptoms				
Skin rash on hands or forearms	6 (2.1)	5 (1.8)	1 (0.4)	0 (0.0)
Skin rash on face or neck	1 (0.4)	1 (0.4)	1 (0.4)	0 (0.0)
Eczema	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Itching hands or forearms	6 (2.1)	5 (1.8)	1 (0.4)	0 (0.0)
Itching face or neck	1 (0.4)	1 (0.4)	1 (0.4)	0 (0.0)
Burning eyes	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Itching eyes	1 (0.4)	1 (0.4)	1 (0.4)	0 (0.0)
Dry eyes	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Sensation of “sand in the eyes”	1 (0.4)	1 (0.4)	0 (0.0)	0 (0.0)
Red eyes	2 (0.7)	2 (0.7)	1 (0.4)	0 (0.0)
Swollen eyes	3 (1.1)	3 (1.1)	2 (0.7)	0 (0.0)
Itching or irritated nose	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Sneezes	31 (11.1)	30 (10.7)	23 (8.2)	0 (0.0)
Bleeding nose	2 (0.7)	2 (0.7)	1 (0.4)	0 (0.0)
Dry throat	1 (0.4)	1 (0.4)	0 (0.0)	0 (0.0)
Flu-like symptoms				
Runny nose	57 (20.4)	54 (19.3)	36 (12.9)	1 (0.4)
Stuffy or blocked nose	52 (18.6)	51 (18.2)	32 (11.4)	1 (0.4)
Sore throat	34 (12.1)	34 (12.1)	18 (6.4)	0 (0.0)
Feeling like getting a cold	7 (2.5)	6 (2.1)	4 (1.4)	1 (0.4)
Fatigue	1 (0.4)	1 (0.4)	0 (0.0)	0 (0.0)
Having a cold	11 (3.9)	9 (3.2)	5 (1.8)	1 (0.4)
Influenza or fever	7 (2.5)	7 (2.5)	0 (0.0)	0 (0.0)
Muscle pain				
Headache	8 (2.9)	7 (2.5)	4 (1.4)	0 (0.0)
Malaise	1 (0.4)	1 (0.4)	1 (0.4)	0 (0.0)

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