The Impact of School Building Conditions on Student Absenteeism in Upstate New York

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Objectives. We investigated Upstate New York school building conditions and examined the associations between school absenteeism and building condition problems.

Methods. We merged data from the 2005 Building Condition Survey of Upstate New York schools with 2005 New York State Education Department student absenteeism data at the individual school level and evaluated associations between building conditions and absenteeism at or above the 90th percentile.

Results. After adjustment for confounders, student absenteeism was associated with visible mold (odds ratio [OR] = 2.22; 95% confidence interval [CI] = 1.34, 3.68), humidity (OR = 3.07; 95% CI = 1.37, 6.89), poor ventilation (OR = 3.10; 95% CI = 1.79, 5.37), vermin (OR = 2.23; 95% CI = 1.32, 3.76), 6 or more individual building condition problems (OR = 2.97; 95% CI = 1.84, 4.79), and building system or structural problems related to these conditions. Schools in lower socioeconomic districts and schools attended by younger students showed the strongest associations between poor building conditions and absenteeism.

Conclusions. We found associations between student absenteeism and adverse school building conditions. Future studies should confirm these findings and prioritize strategies for school condition improvements. (*Am J Public Health.* 2010;100:1679–1686. doi:10.2105/AJPH.2009.165324)

School building conditions[1–3] and school absenteeism[4–7] have been associated with student health. Asthma is one of the leading causes of student absenteeism,[4,8] and respiratory infections likely account for a substantial fraction of short-term illness-related absenteeism[8] among children with[9] and without asthma. Poor building conditions may contribute to these respiratory problems, resulting in greater school absenteeism or poorer performance.[4,8] However, few studies[8,10–14] have evaluated associations between school building conditions and student absenteeism.

Several studies have found associations between parent- or caregiver-reported school absenteeism and exposures to adverse environmental conditions at home.[15,16] Although existing literature has suggested associations between building conditions and school absenteeism, few studies have looked specifically at students' exposures to adverse school building conditions reported by an objective observer, and these were limited to 1 or 2 exposures.[10–14] Furthermore, some prior studies relied on parental report of student absenteeism rather than using objective school records.[10,14]

Our goal was to build on the knowledge from previous studies by using objective records of students' exposures to adverse school building conditions and student absenteeism. We had access to information on a broad range of building conditions from many schools and were able to evaluate cumulative effects of exposure to multiple building conditions. Because we sampled from all Upstate New York schools, our results should be generalizable to a wide range of schools. Our specific aim was to evaluate the associations between school absenteeism and poor building conditions among Upstate New York schools.

METHODS

This cross-sectional study linked 2005 school building conditions and 2005 school absenteeism, using individual schools as the unit of measurement. Data were available for Upstate New York public schools serving students from kindergarten to grade 12.

Data Sources and Collection

School environmental conditions were reported by independent, certified inspectors, including architects and engineers, hired by each school district in the 2005 Building Condition Survey (BCS) of Upstate New York schools,[17] as required every 5 years by state law. School absenteeism was reported in the 2005 State Education Department (SED) State of Learning Annual Report.[18] Demographic, socioeconomic, and geographic data were obtained at the school district level from the 2000 United States Census.[19] The data sets were linked by the 8-digit school district Basic Education Data System code, school name, and school address.

Types of Exposures

The primary exposures were scores for observed building conditions, including mold (visible mold in classrooms, common areas, supply grilles, and other areas), moisture (visible water damage, active roof and plumbing leaks, condensation in classrooms and other areas, and poor humidity rating), ventilation problems (fresh air intakes near sources of air pollution, blockage or dirt in and around fresh air intakes and ducts, damper malfunction, poor air filter condition, inadequate outside air, and ventilation rating), and vermin (rodents, cockroaches, and other vermin). Condition ratings of system and structural variables that could contribute to or be influenced by these exposures were also evaluated, including heating, ventilation, and air conditioning (HVAC) systems (heat generating, heating fuel and energy, cooling and air conditioning, air handling and ventilation, piped and ducted heating and cooling, and control); plumbing systems (water distribution, drainage, hot water heater, and fixtures); building structures (foundations, structural floors, exterior walls and columns, chimneys, exterior doors, windows, skylights, roofs, interior walls, floor finish, ceilings,

interior doors, and swimming pool); and building age. Data coded as "not assessed" or "unable to determine" were recoded as missing data.

Signs of mold, moisture, ventilation problems, and vermin were expressed dichotomously as "yes" or "no." Humidity and ventilation ratings and fresh air filter condition were dichotomized as "good or fair" versus "poor." Ratings of HVAC and plumbing systems and building structures were dichotomized as "excellent or satisfactory" versus "unsatisfactory, nonfunctioning, or critical failure." Building age was dichotomized as newer than or at least as old as the median (50 years).

Collective measures of exposure to mold, moisture, ventilation problems, and vermin included 1 or more problems in a given category ("any mold," "any moisture," "any ventilation problem," or "any vermin"). Cumulative measures of exposure to mold, moisture, ventilation problems, and vermin included "any problem" (1 or more problems in any category) and "all problems" (at least 1 problem in each category). The sum of individual measures over all 4 groups was categorized into 0, 1 or 2, 3 to 5, or 6 or more problems on the basis of natural break points in the data, in the absence of existing literature suggesting comparable break points. Cumulative effects within each group of conditions (mold, moisture, ventilation problems, and vermin) were also evaluated and were categorized on the basis of natural break points in the data.

Primary Outcome

The primary outcome was the average daily absenteeism from each Upstate New York school reported in 2005, calculated as 1.00 minus the average daily proportion of students attending school over the school year. Because the literature did not suggest other meaningful breakpoints, such as the mean absenteeism associated with poor performance, school absenteeism was dichotomized as at or above versus less than the 90th percentile.

Covariates

Many of the potential confounders and effect modifiers considered in this study were related to socioeconomic status (SES). Both SES and urbanicity have been associated with poor home conditions,[16,20–24] and other studies have found associations between SES and school absenteeism[25,26] among children with asthma. High school students have higher rates of school absences.[4] Therefore, the percentage of students qualifying for a free or reduced-price lunch because of poor SES (surrogate for SES), school district urbanicity (city vs suburban and rural), attendance by high school students (schools containing any students in grades 9 through 12), pupil–teacher ratio, expenditure per pupil, and school population density were evaluated for confounding and effect modification in multivariate logistic regression models.

Statistical Analysis

On crude analysis, the odds ratio (OR) was of the same order of magnitude and direction as the prevalence ratio and was used to estimate associations. Using multivariate logistic regression, we performed separate adjusted models for each exposure and absenteeism at or above the 90th percentile. All covariates were included in the initial model, evaluated for confounding and effect modification by a negative log-likelihood test (with $P<.05$ considered statistically significant), and removed by backward elimination as indicated. Stratified analysis was performed if these tests suggested effect modification. SAS version 9.1 (SAS Institute, Cary, NC) was used for all analyses.

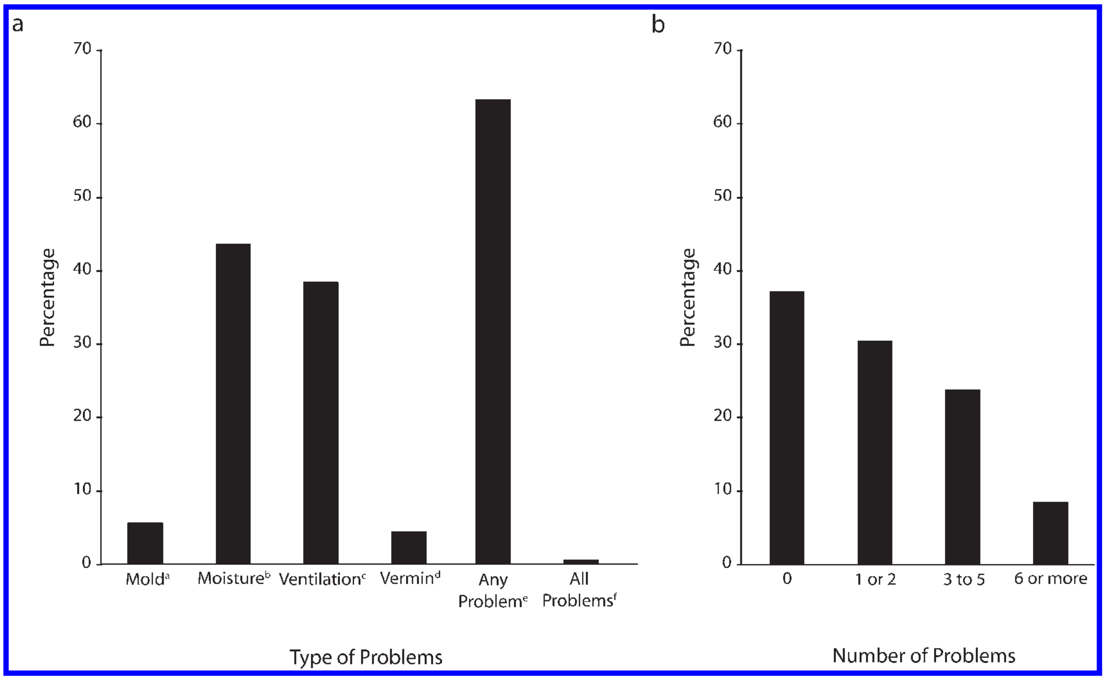
RESULTS

The 2005 BCS results were available for 3272 Upstate New York schools. For schools with BCS data for more than 1 building, the building occupied by the largest number of students was chosen; in all but 30 schools, the largest building was occupied by over 70% of the students. The 2005 SED State of Learning Annual Report data were available for 3753 schools. After the data sets were merged, 2796 Upstate New York Schools had data in both the BCS and SED data sets. Schools missing absence data (1.1%) or with a reported average daily absenteeism of 100% (0.54%) were excluded from the analysis, leaving 2751 schools attended by over 1.6 million students in the merged data set. Six schools had an average daily absenteeism of 0%, but were included in the analysis because their exclusion did not change the results. Of the 2751 schools with valid absenteeism data, the median proportion of daily student absenteeism was 5% and the 90th percentile was 7%, with a range of 0 to 29%. The daily absenteeism distribution was similar to the distributions reported in 2004 and 2006.

Figure 1 shows the reported frequencies of "any mold," "any moisture," "any ventilation problem," "any vermin," and cumulative exposure to these building condition problems. At least 1 rating of "unsatisfactory, nonfunctioning, or critical failure" was seen for HVAC or plumbing systems in 45% of schools and for building structures in 83% of schools, including for air handling and ventilation systems (20%), control systems (13%), windows (19%), skylights (18%), and roofs (20%). The majority of exposure variables had complete data (data missing for less than 5% of schools), with the exception of inadequate outside air (35%) and overall ventilation rating (17%); these variables remained in the analysis because their exclusion did not change the results.

Building Conditions and Absenteeism

As shown in Table 1, school absenteeism for all schools combined was associated with a number of mold, moisture, ventilation, and vermin problems. School absenteeism was most strongly associated with the presence of cockroaches (OR=5.19; 95% confidence interval [CI]=2.37, 11.4), poor overall humidity rating (OR=3.07; 95% CI=1.37, 6.89), and poor overall ventilation rating (OR=3.10; 95% CI=1.79, 5.37). School absenteeism was also associated with mold in common areas (OR=2.94; 95% CI=1.48, 5.84), active plumbing leaks in classrooms (OR=2.29; 95% CI=1.04, 5.04) and other areas (OR=2.08; 95% CI=1.14, 3.80), condensation in other areas (OR=2.35; 95% CI=1.43, 3.87), air intake near garbage storage areas (OR=2.90; 95% CI=1.46, 5.76), fresh air intake blockage (OR=2.23; 95% CI=1.40, 3.57), damper malfunction (OR=2.50; 95% CI=1.63, 3.83), inadequate outside air (OR=2.89; 95% CI=1.78, 4.70), and the presence of rodents (OR=2.22; 95% CI=1.14, 4.31). School absenteeism was not significantly associated with mold in classrooms (OR=2.05), visible water damage in classrooms (OR=1.15), active roof leaks in classrooms (OR=1.06) and other areas (OR=1.37), having fresh air intake near bus



[a]Presence of any measure of mold.
[b]Presence of any measure of moisture or poor humidity rating.
[c]Presence of any ventilation problem or poor filter or ventilation ratings.
[d]Any signs of vermin.
[e]At least 1 problem with mold, moisture, ventilation, or vermin.
[f]At least 1 problem with mold, moisture, ventilation, and vermin (i.e., with at least one problem in all categories).

FIGURE 1—Upstate New York schools (n=2751) with mold, moisture, ventilation, or vermin problems, by (a) type of problems and (b) number of problems: Building Condition Survey, 2005.

loading (OR=0.71) or truck delivery areas (OR=1.41), or air filter condition (OR=2.04).

Among the summary measures of exposure to mold, moisture, ventilation problems, and vermin, school absenteeism was associated with "any mold" (OR=2.22; 95% CI=1.34, 3.68), "any ventilation problem" (OR=1.44; 95% CI=1.07, 1.93), "any vermin" (OR=2.23; 95% CI=1.32, 3.76), and "all exposures" (OR=3.70; 95% CI=1.14, 12.1; Table 1). School absenteeism was not associated with "any moisture" or "any exposure." A dose–response was seen for greater ORs of absenteeism with exposure to 6 or more building condition problems (OR=2.97; 95% CI=1.84, 4.79; Figure 2) and 3 or more ventilation problems (Figure 2), but not for cumulative mold, moisture, and vermin problems.

As shown in Table 2, school absenteeism was associated with less-than-satisfactory ratings of HVAC, plumbing systems, and structural measures and was most strongly associated with problems concerning heating fuel and energy systems (OR=3.31; 95% CI=1.76, 6.24), piped heating and cooling systems (OR=2.24; 95% CI=1.43, 3.51), control systems (OR=2.29; 95% CI=1.53, 3.45), water distribution systems (OR=2.29; 95% CI=1.32, 3.96), interior bearing walls (OR=3.09; 95% CI=1.26, 7.59), other interior walls (OR=2.56; 95% CI=1.46, 4.51), and interior door units (OR=2.33; 95% CI=1.52, 3.56). School absenteeism was not significantly associated with less-than-satisfactory conditions of other measures, including air conditioning, ducted heating and cooling systems, plumbing drainage systems, hot water heaters, plumbing fixtures, foundations, structural floors, chimneys, roofs, and older building age.

In multivariate analysis, effect modification was suggested between the following building conditions and demographic factors: (1) the presence of moisture and pupil–teacher ratio (P=.001), (2) poor ventilation and school district urbanicity (P=.05), and (3) poor ventilation and attendance by high school students (P=.008). In stratified models, school absenteeism was significantly associated with moisture among schools with a pupil–teacher ratio at or above the 50th percentile (OR=1.51; 95% CI=1.01, 2.26; OR=0.70 for schools with a pupil–teacher ratio below the 50th percentile) and with poor ventilation rating among city schools (OR=4.39; 95% CI=2.20, 8.77; OR=0.73 for suburban and rural schools) and schools without high school students (OR=4.24; 95% CI=2.32, 7.74; OR=0.37 for schools with high school students).

Residual Confounding

There was concern that residual confounding or effect modification might exist for school district SES, despite adjustment for the surrogate measure, the percentage of students qualifying for a free or reduced-price lunch. To further evaluate the effects of SES, schools were stratified into tertiles by this

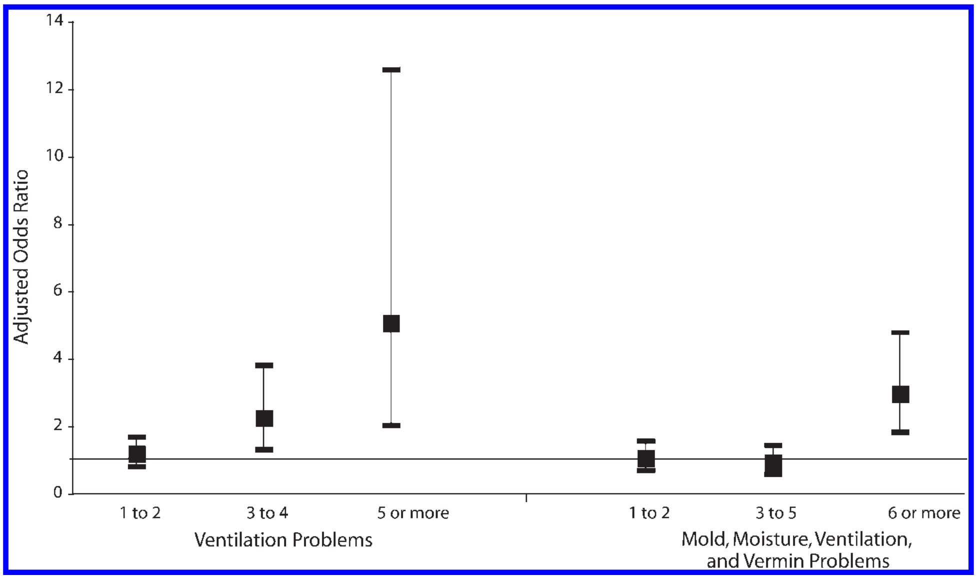
TABLE 1—Adjusted Odds Ratios (AORs) of Student Absenteeism Associated With Exposure to Mold, Moisture, Ventilation Problems, and Vermin in Schools, by School Socioeconomic Status (SES): Building Condition Survey, Upstate New York, 2005

Exposure	All Schools (n = 2751), AOR[a] (95% CI)	Schools in Lowest-SES Districts[b] (n = 932), AOR[c] (95% CI)	Schools in Higher-SES Districts[d] (n = 1819), AOR[c] (95% CI)
Mold			
Any mold	2.22 (1.34, 3.68)	2.15 (1.21, 3.82)	0.50 (0.07, 3.71)
Mold visible in classroom	2.05 (0.94, 4.47)	2.13 (0.97, 4.68)	. . .
Mold visible in common areas	2.94 (1.48, 5.84)	3.23 (1.58, 6.58)	. . .
Mold in supply grilles	2.45 (0.53, 11.7)	3.12 (0.59, 16.6)	. . .
Mold visible in other areas	1.49 (0.61, 3.62)	1.46 (0.57, 3.74)	0.78 (0.10, 5.87)
Moisture			
Any moisture	1.27 (0.95, 1.71)	1.36 (0.96, 1.94)	0.60 (0.32, 1.12)
Visible water damage in classroom	1.15 (0.81, 1.62)	1.37 (0.93, 2.01)	0.43 (0.18, 1.03)
Active roof leaks in classroom	1.06 (0.71, 1.58)	1.18 (0.76, 1.83)	0.57 (0.22, 1.48)
Active plumbing leaks in classroom	2.29 (1.04, 5.04)	2.33 (0.99, 5.50)	2.39 (0.53, 10.8)
Condensation in classroom	1.43 (0.76, 2.69)	1.45 (0.72, 2.92)	0.85 (0.20 3.64)
Visible water damage in other areas	1.43 (1.03, 1.98)	1.53 (1.06, 2.22)	0.67 (0.33, 1.37)
Active roof leaks in other areas	1.37 (0.95, 1.96)	1.41 (0.94, 2.11)	0.79 (0.37, 1.67)
Active plumbing leaks in other areas	2.08 (1.14, 3.80)	2.08 (1.07, 4.05)	0.88 (0.20, 3.78)
Condensation in other areas	2.35 (1.43, 3.87)	2.08 (1.18, 3.70)	1.44 (0.54, 3.82)
Poor humidity rating	3.07 (1.37, 6.89)	2.39 (0.97, 5.85)	4.01 (0.87, 18.5)
Ventilation problems			
Any ventilation problem	1.44 (1.07, 1.93)	1.68 (1.18, 2.40)	0.98 (0.54, 1.80)
Air intake near bus loading	0.71 (0.41, 1.25)	1.05 (0.55, 2.02)	0.28 (0.067, 1.19)
Air intake near truck delivery	1.41 (0.86, 2.31)	1.84 (1.05, 3.24)	1.05 (0.40, 2.75)
Air intake near garbage storage	2.90 (1.46, 5.76)	3.99 (1.63, 9.78)	2.19 (0.74, 6.48)
Dirt, dust, or debris around intake	1.24 (0.60, 2.54)	1.43 (0.65, 3.12)	0.50 (0.07, 3.85)
Fresh air intake blockage	2.23 (1.40, 3.57)	1.96 (1.16, 3.33)	1.90 (0.78, 4.68)
Dirt, dust, or debris in ductwork	1.86 (1.14, 3.04)	3.24 (1.82, 5.77)	0.81 (0.28, 2.33)
Damper malfunction	2.50 (1.63, 3.83)	2.75 (1.67, 4.53)	1.68 (0.75, 3.75)
Air filter condition	2.04 (0.65, 6.47)	3.91 (0.98, 15.6)	. . .
Inadequate outside air	2.89 (1.78, 4.70)	2.61 (1.55, 4.40)	1.16 (0.34, 4.03)
Poor ventilation and indoor air quality rating	3.10 (1.79, 5.37)	3.48 (1.89, 6.41)	0.49 (0.065, 3.66)
Vermin			
Any vermin	2.23 (1.32, 3.76)	1.77 (0.99, 3.18)	1.46 (0.34, 6.36)
Rodents	2.22 (1.14, 4.31)	1.92 (0.95, 3.87)	1.90 (0.43, 8.42)
Cockroaches	5.19 (2.37, 11.4)	3.53 (1.51, 8.27)	4.08 (0.87, 19.2)
Other vermin	2.92 (1.22, 6.94)	2.17 (0.89, 5.29)	4.02 (0.47, 34.0)
Any exposure	1.29 (0.93, 1.80)	1.36 (0.94, 1.98)	0.63 (0.34, 1.14)
All exposures	3.70 (1.14, 12.1)	2.98 (0.92, 9.66)	. . .

Note. CI = confidence interval. Ellipses indicate that figures could not be calculated.
[a]Adjusted for percentage of students qualifying for a free or reduced-price lunch, school district urbanicity, attendance by high school students, and pupil–teacher ratio.
[b]Highest tertile of percentage of students qualifying for a free or reduced-price lunch.
[c]Adjusted for school district urbanicity, attendance by high school students, and pupil–teacher ratio.
[d]Lower 2 tertiles of percentage of students qualifying for a free or reduced-price lunch.

surrogate SES measure. As shown in Tables 1 and 2, absenteeism was associated with building condition problems among schools in the lowest-SES districts; these associations were weaker for schools in districts with higher SES.

To further evaluate for residual confounding or effect modification by student age, schools were stratified into elementary, middle, and high schools. Among elementary schools, absenteeism was associated with ventilation problems (OR = 2.33; 95% CI = 1.38, 3.93),



Note. Odds ratios were adjusted for percentage of students qualifying for free or reduced-price lunch, school district urbanicity, attendance by high school students, and pupil–teacher ratio. The reference group was zero building condition problems.

FIGURE 2—Cumulative adverse school building conditions (n = 2751): Building Condition Survey, Upstate New York, 2005.

vermin (OR=2.59; 95% CI=1.16, 5.76), and with having 6 or more problems with mold, moisture, ventilation, or vermin (OR=5.48; 95% CI=2.58, 11.7). For middle schools, there were trends toward associations of absenteeism with moisture (OR=2.19; 95% CI=0.89, 5.42) and with having 6 or more problems (OR=2.19; 95% CI=0.61, 7.91). Among high schools, there was a trend toward association between absenteeism and mold problems (OR=2.40; 95% CI=0.86, 6.74).

DISCUSSION

We found associations between greater school absenteeism and exposure to adverse building conditions, such as mold, moisture, ventilation problems, vermin, and a few related system and structural problems, after adjustment for SES, school district urbanicity, student age, and pupil–teacher ratio. Schools with 6 or more adverse exposures to mold, moisture, ventilation, or vermin also had increased odds of higher absenteeism.

Although studies have documented that school building condition problems involving mold and moisture,[1,3,27–29] ventilation,[3,29,30] and vermin[29,31–33] and parent-reported home exposures to adverse environmental conditions have been associated with student absenteeism,[15] few existing studies have directly evaluated the associations between school absenteeism and exposure to these school building conditions. One small study of 12 schools found more absenteeism among schools with lower humidity, but it mentioned that the schools with low humidity were older and attended by students of lower SES.[12] An Australian study of 388 elementary school students found strong evidence of an association between school or home nitrogen dioxide (NO_2) levels above 40 parts per billion and parent-reported student absenteeism (OR=1.92; 95% CI=1.13, 3.25).[10] A 10% to 20% increase in absenteeism was seen with an increase of 1000 parts per million in the difference between school indoor and outdoor carbon dioxide (CO_2),[11] and greater student absenteeism has been associated with higher levels of airborne particulates in a day-care setting,[13] suggesting that school ventilation problems may affect absenteeism. Schools with greater mouse allergen levels have shown a trend toward greater school absenteeism due to asthma.[14] A previous study also showed associations between school structural problems and health outcomes that may be related to absenteeism.[2]

Of the previous studies of school building environments, many have focused on measurements of 1 pollutant, such as NO_2,[10] CO_2,[11] or particulate matter,[13] rather than taking many exposures into account, or have relied on parental report of absenteeism.[10,14] Other evaluations of school absenteeism and its association with moisture[12] and airborne particulates[13] used official government records of attendance for a small number of schools but did not discuss potential sources of selection bias or take confounders, such as SES, into consideration. Some studies evaluating the association of school absenteeism with problems involving mold or moisture,[15] ventilation,[10] and vermin[14] have included home exposures to these conditions; such home exposure could cause allergen sensitization that predates exposure at school, contribute to cumulative building condition exposure, be related to SES, and account for some of the residual confounding by SES in this study. A study of office workers corroborates these school-based findings, showing a 50% increase in short-term sick leave associated with poorer ventilation.[34]

For absenteeism due to illness, associations between school building conditions and student absenteeism are biologically plausible, and poor respiratory health is a possible intermediary on the causal pathway. Moisture and dampness can support mold growth[35,36] and the proliferation of dust mites,[35] which may produce allergic respiratory symptoms, and dampness can adversely affect respiratory health by aggravating allergy symptoms or promoting

TABLE 2—Adjusted Odds Ratios (AORs) of Student Absenteeism Associated With Exposure to Less-Than-Satisfactory System and Structural Building Conditions of Schools, by School Socioecomic Status (SES): Building Condition Survey, Upstate New York, 2005

Conditions	All Schools (n = 2751), AOR[a] (95% CI)	Schools in Lowest-SES Districts[b] (n = 932), AOR[c] (95% CI)	Schools in Higher-SES Districts[d] (n = 1819), AOR[c] (95% CI)
Building systems			
Heat generating systems	1.62 (1.02, 2.55)	1.65 (0.99, 2.74)	0.56 (0.17, 1.88)
Heating fuel and energy systems	3.31 (1.76, 6.24)	3.28 (1.58, 6.83)	1.97 (0.57, 6.82)
Cooling and air conditioning systems	0.87 (0.45, 1.68)	0.72 (0.36, 1.44)	. . .
Air handling and ventilation systems	1.68 (1.16, 2.42)	1.58 (1.05, 2.38)	0.81 (0.38, 1.74)
Piped heating and cooling systems	2.24 (1.43, 3.51)	2.00 (1.18, 3.38)	1.39 (0.60, 3.24)
Ducted heating and cooling systems	1.09 (0.57, 2.09)	1.16 (0.57, 2.36)	0.28 (0.04, 2.12)
Control systems	2.29 (1.53, 3.45)	2.52 (1.58, 4.02)	1.40 (0.63, 3.10)
Water distribution systems	2.29 (1.32, 3.96)	2.27 (1.22, 4.24)	1.31 (0.39, 4.42)
Plumbing drainage system	1.03 (0.52, 2.06)	1.53 (0.76, 3.10)	. . .
Hot water heater	1.08 (0.63, 1.85)	1.14 (0.64, 2.02)	0.22 (0.03, 1.64)
Plumbing fixtures	1.29 (0.78, 2.14)	1.19 (0.68, 2.10)	0.94 (0.32, 2.70)
Building structures			
Foundation	1.68 (0.71, 3.99)	1.02 (0.39, 2.65)	1.46 (0.19, 11.4)
Structural floors	1.47 (0.56, 3.86)	2.06 (0.72, 5.91)	. . .
Exterior walls and columns	1.91 (1.26, 2.88)	1.93 (1.22, 3.06)	0.70 (0.24, 2.04)
Chimneys	1.34 (0.76, 2.37)	1.44 (0.77, 2.70)	0.98 (0.34, 2.87)
Exterior door unit	1.50 (0.99, 2.29)	1.43 (0.89, 2.28)	1.01 (0.39, 2.65)
Exterior door hardware	1.70 (1.10, 2.61)	1.71 (1.06, 2.77)	0.81 (0.28, 2.33)
Windows	1.74 (1.22, 2.48)	1.78 (1.20, 2.63)	1.31 (0.63, 2.71)
Skylights	1.33 (0.84, 2.11)	1.20 (0.71, 2.02)	0.75 (0.28, 2.00)
Roofs	1.24 (0.86, 1.78)	1.26 (0.85, 1.87)	0.67 (0.29, 1.56)
Interior bearing walls	3.09 (1.26, 7.59)	4.09 (1.48, 11.3)	. . .
Other interior walls	2.56 (1.46, 4.51)	2.34 (1.20, 4.57)	0.90 (0.21, 3.84)
Floor finish	1.55 (1.04, 2.32)	1.43 (0.92, 2.22)	1.27 (0.52, 3.10)
Ceilings	1.64 (1.04, 2.59)	1.81 (1.08, 3.04)	0.94 (0.33, 2.71)
Interior door units	2.33 (1.52, 3.56)	2.34 (1.45, 3.78)	1.64 (0.71, 3.78)
Interior door hardware	1.47 (0.99, 2.16)	1.62 (1.06, 2.48)	1.11 (0.48, 2.54)
Swimming pool	1.09 (0.43, 2.78)	1.04 (0.37, 2.87)	1.06 (0.12, 9.13)
Older building	0.95 (0.69, 1.30)	1.03 (0.73, 1.45)	1.21 (0.67, 2.19)

Note. CI = confidence interval. Ellipses indicate that figures could not be calculated.
[a]Adjusted for percentage of students qualifying for a free or reduced-price lunch, school district urbanicity, attendance by high school students, and pupil–teacher ratio.
[b]Highest tertile of percentage of students qualifying for a free or reduced-price lunch.
[c]Adjusted for school district urbanicity, attendance by high school students, and pupil–teacher ratio.
[d]Lower 2 tertiles of percentage of students qualifying for a free or reduced-price lunch.

infections. Poor ventilation may allow an accumulation of particulates, pollutants, and allergens inside school buildings,[3] and decreased air circulation may increase transmission of respiratory infections. Vermin allergens may also trigger allergic respiratory symptoms.[16] Building structural problems,[2] such as heating or air conditioning systems venting near an air intake, control systems malfunctioning to allow uncomfortable temperatures, or holes in the walls, doors, windows, or ceilings allowing moisture or vermin access, may contribute to these exposures.

Assessment of interaction by stratified analysis showed that the associations between school absenteeism and poor ventilation, vermin, and cumulative exposure to building condition problems were greater for younger students. Although previous studies have not compared absenteeism and school building conditions among children of varying ages, young children are known to be more susceptible to airborne pollutants than older children or adults because of their greater activity, smaller airways, and faster ventilation rates.[37,38] Young children may also be more susceptible to vermin-related exposures[39] because they spend more time close to floor level. In this study, absenteeism was also associated with ventilation problems among city schools,

and stratification by SES illustrated that building conditions were most strongly associated with absenteeism among lower-SES school districts. The respiratory health disparities among children living in urban environments and children of lower SES have been well studied,[40,41] but the contribution of school building conditions to school absenteeism in these populations needs further investigation. Factors associated with lower SES, such as poor access to health care and lack of disease management, may make these children more susceptible to adverse environmental conditions, and poor housing may increase their allergen sensitization and cumulative exposure to building problems similar to those observed in schools.

Strengths and Limitations

This study was unique in that it evaluated a large number of building conditions directly observed by independent, certified inspectors and linked these exposures with official school records of absenteeism from the New York SED. We repeated the analyses using a breakpoint of absenteeism at or above the 75th percentile (6% average absenteeism); the magnitude and direction of associations were similar, suggesting robust associations. We anticipated that the results of this study would allow us to identify schools that had greater absenteeism associated with poor building conditions, with the goal of developing a public health initiative to improve conditions in these schools and to reduce the detriment to student health and attendance. Previous studies have suggested that schools with an indoor air quality management program reported lower frequencies of asthma attacks and school absenteeism, but that fewer than half of schools nationwide have implemented policies to manage these building conditions.[42,43] The results of this study are of importance to schools and school districts, and may have an impact on school funding priorities.

To ensure that our study sample was representative of Upstate New York schools, we attempted to minimize selection bias by using data sets that should have included all Upstate New York schools. The SED absenteeism distribution was similar for all schools and for schools whose SED data could be linked with BCS exposure data, suggesting that the schools included in the analysis were representative of the target population with respect to the outcome. Furthermore, the BCS exposure frequencies were similar for all schools and for schools whose BCS data could be linked with SED absenteeism data, suggesting that the schools included in the analysis were representative of the target population with respect to the exposures.

Fifty percent of Buffalo, New York, city schools in the SED data set were excluded because they could not be linked to schools in the BCS data set; some of these schools may not have participated in the BCS, and others may not have had consistent name and address data reported in the BCS and SED data sets. However, the frequencies of BCS exposure measures were similar for all Buffalo schools with BCS data and for Buffalo schools with BCS data matched to absenteeism data, and the absenteeism outcome distributions were similar for Buffalo schools with and without matched BCS exposure data, suggesting that the Buffalo schools included in the study were representative of the Buffalo school district with respect to the exposures and outcome.

Information bias, which was also a concern for this large, population-based study, was minimized through use of existing, official data sets for both the exposure and outcome variables; these data sets were recorded independently and without a connection to the study. Official school records, the most accurate method of determining school absence retrospectively, were used as the outcome data. Another potential source of bias included reporting bias introduced by the participation of multiple school building inspectors. However, the inspectors were certified and should have been able to perform the inspection at the minimum acceptable standard. In addition, the inspectors were not associated with the individual schools or with the study and should not have been systematically more likely to over- or underreport problems. If misclassification by exposure occurred, it should not have been associated with the outcome, resulting in nondifferential biasing of the study results toward the null.

Potential limitations of this study included the possibility of additional confounding by outdoor exposures such as traffic pollution; home exposures such as mold, moisture, poor indoor air quality, vermin, or secondhand smoke; and family characteristics including parental education. In addition, absenteeism due to illness or other reasons could not be distinguished. The study's ecological design did not allow collection of information on individual health outcomes or reasons for absenteeism. Objective laboratory measures of the exposures, such as surface humidity readings, CO_2 levels, or vermin allergen levels, were not collected at the time of the survey.

Conclusions

Our findings suggest that mold, moisture, ventilation problems, vermin, cumulative exposure, and a number of related system and structural problems were associated with school absenteeism in Upstate New York schools. Although further study will be necessary to confirm the findings of this cross-sectional ecological study, schools should continue to work with public health officials to improve their building conditions. Future building condition surveys will be used to monitor trends in school condition and identify conditions with the greatest effects on attendance over time, so that schools with limited resources may make changes that will have the greatest impact. In addition to observation of conditions, future studies may collect objective measures of surface humidity, CO_2 levels, and vermin allergen levels in a subsample of schools. Survey data from teachers and school nurses regarding building condition exposures, respiratory and other symptoms, and reasons for school absenteeism should also be collected. ■

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Contributors

E. Simons contributed to study planning, conducted the data management and analysis, and wrote the article. S.-A. Hwang and E. F. Fitzgerald mentored the Building Condition Survey project and provided feedback on the

analysis and article. C. Kielb worked extensively with the Building Condition Survey project and data set and reviewed the article. S. Lin conceptualized the study and contributed extensively to the project, analysis, and article preparation.

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