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Original Contribution

A Matched Analysis of the Association Between Federally Mandated Smoke-Free Housing Policies and Health Outcomes Among Medicaid-Enrolled Children in Subsidized Housing, New York City, 2015–2019

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Smoke-free housing policies are intended to reduce the deleterious health effects of secondhand smoke exposure, but there is limited evidence regarding their health impacts. We examined associations between implementation of a federal smoke-free housing rule by the New York City Housing Authority (NYCHA) and pediatric Medicaid claims for asthma, lower respiratory tract infections, and upper respiratory tract infections in the early post–policy intervention period. We used geocoded address data to match children living in tax lots with NYCHA buildings (exposed to the policy) to children living in lots with other subsidized housing (unexposed to the policy). We constructed longitudinal difference-in-differences models to assess relative changes in monthly rates of claims between November 1, 2015, and December 31, 2019 (the policy was introduced on July 30, 2018). We also examined effect modification by baseline age group ($\leq$2, 3–6, or 7–15 years). In New York City, introduction of a smoke-free policy was not associated with lower rates of Medicaid claims for any outcomes in the early postpolicy period. Exposure to the smoke-free policy was associated with slightly higher than expected rates of outpatient upper respiratory tract infection claims (incidence rate ratio = 1.05, 95% confidence interval: 1.01, 1.08), a result most pronounced among children aged 3–6 years. Ongoing monitoring is essential to understanding long-term health impacts of smoke-free housing policies.

asthma; housing; public policy; respiratory infections; secondhand smoke; smoking

Abbreviations: BBL, borough-block-lot parcel; CBG, census block group; CI, confidence interval; DiD, difference in differences; HUD, US Department of Housing and Urban Development; IRR, incidence rate ratio; LRI, lower respiratory tract infection; NYCHA, New York City Housing Authority; $PM_{2.5}$, particulate matter with an aerodynamic diameter less than or equal to 2.5 µm; SHS, secondhand smoke; URI, upper respiratory tract infection.

Editor's note: *An invited commentary on this article appears on page 34, and the authors' response appears on page 39.*

Exposure to secondhand smoke (SHS) is associated with a range of pediatric health outcomes, including respiratory infections, middle ear disease, cough, phlegm, asthma, and wheeze-related illnesses (1). Despite substantial declines in the prevalence of SHS exposure in the United States in recent decades, levels of SHS exposure among children remain high. According to biomarker data from the National Health and Nutrition Examination Survey, the prevalence of SHS exposure among children aged 3–11 years was nearly 40% in 2017–2018 (2). Moreover, children and adults from lower-income households are considerably more likely to be exposed to SHS than individuals in higher-income households (2, 3). Prior research has established that housing environments are critical determinants of SHS exposure prevalence and disparities. Youth who live with 2 or more smokers are more than 3 times as likely to be exposed to SHS as youth who do not live with a smoker (4). In addition, adults and children in multifamily housing are at increased risk of SHS exposure compared with those in single-family homes, partly due to transfer of SHS between smoking and nonsmoking apartments (5–8).

Given the central role of home environments in shaping SHS exposure patterns, many municipalities and housing developments across the United States have introduced smoke-free housing policies. In 2016, the US Department of Housing and Urban Development (HUD) issued a nationwide rule that required all public housing agencies—organizations that receive federal financing to manage rental housing developments for low-income families (9)—to implement smoke-free policies in housing developments by July 30, 2018 (10). The potential impact of the HUD rule is substantial, given that nearly 1 million households in the United States reside in public housing developments (9). Yet, to date, evidence on the effectiveness of smoke-free policies in multifamily housing is mixed. Single-city evaluations using self-reported data have generally found that smoke-free policies in multifamily housing are associated with decreases in SHS exposure, including in nonsmoking households (11–13). However, a survey-based study of 6 US communities found that smoke-free policies were associated with reduced SHS incursions among residents in market-rate housing but not in subsidized housing (14). Evaluations using objective measures of SHS exposure, such as airborne nicotine and fine particulate matter (particulate matter with an aerodynamic diameter less than or equal to 2.5 µm ($PM_{2.5}$)), are also inconsistent. Within public housing developments in Philadelphia, Pennsylvania, a smoke-free policy was associated with a significant decrease in airborne nicotine in public areas during the year following policy implementation (15), while a smoke-free policy in Norfolk, Virginia, public housing developments was associated with increased $PM_{2.5}$ and airborne nicotine levels 1 year after the policy was introduced (16). Two studies carried out in Boston Housing Authority (Boston, Massachusetts) developments found that smoke-free policies were associated with lower levels of $PM_{2.5}$ in households (6) and common areas (17). However, a third evaluation of Boston Housing Authority smoke-free policies found that airborne nicotine levels in apartments without resident smokers declined at similar rates in Boston Housing Authority and comparison developments after policy implementation (18). In New York City (NYC), changes in airborne nicotine levels in common areas, stairwells, and nonsmoking apartments 1 year after implementation of a smoke-free policy were not significantly different in NYC Housing Authority (NYCHA) buildings compared with control areas in another type of subsidized housing (the HUD Section 8 voucher program) (19).

While evidence regarding smoke-free housing and air quality is somewhat equivocal, even less is known about associations between smoke-free policies in public housing developments and SHS-attributable health outcomes. We are aware of only 1 health-outcome–focused evaluation of a smoke-free public housing policy within the United States. A survey-based analysis conducted among Colorado public housing residents before and after the implementation of a smoke-free policy found that there was a significant decrease in self-reported breathing problems after the policy was introduced (20). Observed changes in other health outcomes did not reach statistical significance (20). Studies of other policy interventions targeting SHS exposure (e.g., state and local smoke-free laws) suggest that these restrictions may have significant impacts on pediatric health outcomes. For example, a meta-analysis focused on smoke-free laws in workplaces and public areas found that these policies were associated with a 10% reduction in pediatric hospitalizations for asthma (21). Rigorous studies to further our understanding of the associations between smoke-free housing policies and health outcomes are critically needed (22), as these policies have the potential to affect long-standing disparities in respiratory health morbidity across housing environments (23, 24).

In this study, we sought to evaluate the impact of the HUD rule in NYC by examining associations between the introduction of a HUD-compliant smoke-free policy in NYCHA developments and subsequent changes in pediatric health outcomes for SHS-sensitive conditions (asthma, lower respiratory tract infections (LRIs), and upper respiratory tract infections (URIs)) using Medicaid claims data. The NYCHA policy offers a unique opportunity to employ a quasi-experimental evaluation approach, given the sizeable population of individuals residing in NYCHA buildings (subject to the HUD rule) and in other types of subsidized housing in NYC (not subject to the HUD rule). In evaluating the NYCHA smoke-free policy, we contribute to the nascent literature on the potential impact of smoke-free housing policies in public housing on downstream pediatric health outcomes.

METHODS

Sample

We linked NYC Medicaid claims data to borough-block-lot parcels (BBLs) (25), which represent unique tax lot identifiers. Linkages were based on residential addresses of Medicaid recipients in Medicaid eligibility data. Addresses are updated when enrollees in the state's social welfare programs move, as well as annually or semiannually upon enrollment renewal. We constructed a cohort of children enrolled in Medicaid as of November 1, 2015, who either 1) lived in BBLs that contained NYCHA developments or 2) lived in BBLs that contained other HUD-financed programs (e.g., the Section 8 housing voucher program), property tax incentive programs tied to the provision of low-income housing, zoning initiatives, or other city and state housing subsidization programs. We excluded BBLs with subsidized housing associated with the Mitchell-Lama program (26), as it targets moderate- and middle-income families rather than lower-income families. BBLs containing any type of subsidized housing were identified using information from the New York University Furman Center's CoreData.nyc, updated in 2019 (27). We excluded addresses linked to BBLs that were not classified as residential (e.g., commercial and office buildings), as well as BBLs comprised of 1- and 2-family buildings, cooperatives, luxury dwellings, and buildings that were constructed after the year 2000, according to NYC Primary Land Use Tax Lot Output (PLUTO) data (28). We restricted the cohort to children aged 15 years or under at baseline, so that all children in the cohort would remain age-eligible for Children's Medicaid at the time of the policy intervention (July 2018). Finally, we excluded children who were dually eligible for Medicare and Medicaid, given the small number of children ($n < 100$) in this group. We followed the cohort through December 31, 2019.

Outcomes

Outcomes were monthly individual-level counts of health-care encounters in the emergency department and in non–emergency department outpatient settings with any *International Classification of Diseases, Tenth Revision*, diagnosis code associated with asthma, LRI, or URI. We selected these outcome conditions on the basis of their established associations with SHS exposure (1). Conditions were defined using *International Classification of Diseases, Tenth Revision*, code maps from the Global Burden of Disease Study (29) (see Web Table 1, available at https://doi.org/10.1093/aje/kwac089).

Smoke-free housing policy

The smoke-free housing policy was implemented by NYCHA on July 30, 2018. Per HUD regulations, the policy prohibited the smoking of specified tobacco products in all housing developments, including residential units, indoor common areas, and administrative offices and within a 25-foot (7.6-m) perimeter of buildings (10). Consistent with an intention-to-treat approach, all children with a residential address linked to a NYCHA development were considered exposed to the smoke-free housing policy as of August 1, 2018, irrespective of actual policy implementation experience. Children in other types of subsidized housing were considered unexposed to the policy. Given the policy's implementation date, the study period included nearly 3 years (33 months) of prepolicy data and nearly 1.5 years (17 months) of postpolicy data.

Matching and covariates

Children in tax lots comprised of NYCHA developments were matched to children living in tax lots with other types of subsidized housing at baseline. We conducted the matching in 3 stages. In the first stage, we conducted 5:1 nearest-neighbor Mahalanobis distance matching with replacement, within groups exactly matched on age group (≤2, 3–6, or 7–15 years), race/ethnicity (non-Hispanic White, non-Hispanic Black, non-Hispanic Asian, Hispanic, other non-Hispanic, or unknown), sex (male, female), and disability/blindness status. Within these matched groups, Mahalanobis distance matching was conducted using the following characteristics measured at baseline: age (years; continuous), presence of any chronic disease diagnosis, presence of a building with at least 7 floors in the BBL, and several characteristics of the population in the census block group (CBG), including percentage of households with poverty:income ratios less than 1.00 and between 1.00 and 1.24; percentages of Black and Hispanic residents; percentages of persons aged ≤17, 18–49, and ≥50 years; and population density (number of persons/m^2). We also matched on the number of Medicaid enrollment months over the entire pre–policy intervention period and on estimated propensity to live in an NYCHA development derived from a model using the above variables, with the exception of age group. Individual-level variables were obtained from Medicaid data, while BBL and CBG measures were obtained from 2018 PLUTO data and 5-year (2014–2018) estimates from the American Community Survey. We chose not to match on measures of health-care utilization in the pre–policy intervention period given concerns about differential regression to the mean in matched difference-in-differences (DiD) analyses (30). Nearest-neighbor matches were restricted to the area of common support. In order to improve matching within age subgroups, we used a least absolute shrinkage and selection operator (LASSO) procedure to identify important interactions between age subgroup and the above variables included in the Mahalanobis distance match (31). In the final stage, we refitted the propensity score model with the matched data, identified interaction terms, and calculated overlap weights to further balance covariate distributions across groups (31). To assess the effectiveness of the matching approach, we compared standardized differences between overlap-weighted mean values. As expected (since overlap weights are known to achieve near-perfect balance) (31), absolute values of all standardized mean differences were less than 0.04 for the full sample and less than 0.08 within age groups.

Statistical analysis

We conducted a DiD analysis using generalized estimating equations models with a negative binomial distribution and incorporating a first-order autoregressive correlation structure, robust standard errors, and overlap weights. DiD modeling relies on the assumption that outcome trends in the postpolicy period in the comparison group are a valid counterfactual for outcome trends in the treatment group in the absence of the policy (32). This assumption is not empirically testable, but we visually examined the extent to which outcome trends across the two groups in the prepolicy period appeared to be parallel. Regression models included indicators for treatment status (NYCHA vs. comparison), time (pre– vs. post–policy intervention), and their interaction. We examined the statistical significance of the interaction term at the 0.05 level to determine whether outcome trends in the NYCHA group were statistically different from outcome trends in the comparison group in the postpolicy period. Models also included all covariates used in the propensity score estimation and matching, with the exception of total months of Medicaid enrollment. In addition to fitting models for the full sample, we examined the potential for effect modification by age, stratifying the sample by age category at baseline (≤2, 3–6, or 7–15 years). This effect modification analysis was specified a priori, given evidence of the potential for differential drivers of asthma outcomes across age ranges among children (1).

We conducted several sensitivity analyses. First, to address the possibility that associations were partly due to differential Medicaid disenrollment and/or churn between the groups, we fitted models excluding child-months when a child was not enrolled in Medicaid. We constructed 2 additional matched cohorts to include only 1) children who were continuously enrolled in Medicaid over the course of the study period (with an allowable 1-month gap) and 2) children who remained in the same BBL throughout the study period. We also assessed whether our results differed if we defined outcomes on the basis of primary diagnosis code rather than all diagnosis codes. We fitted models excluding data from a 3-month "washout" period following policy implementation, which entailed using postintervention data from November 1, 2018, onwards, instead of August 1, 2018, onwards. Finally, we conducted 2 sensitivity analyses to assess the robustness of our results to unmeasured, potentially confounding characteristics of the housing environment (e.g., general aging and deterioration of buildings). First, we performed a negative control outcome analysis (33), where we examined associations with a housing-sensitive condition (injuries) (34) that we would not expect to be affected by the smoke-free policy. Second, we conducted a "placebo test," in which we specified the postpolicy intervention period as August 2017–July 2018 (1 year before the actual policy introduction date). Significant associations with outcomes in the placebo year would suggest that our main analysis results could be due to residual confounding.

Data processing was conducted in SAS, version 9.4 (SAS Institute, Inc., Cary, North Carolina). All analyses were conducted in Stata, version 16.0 (StataCorp LLC, College Station, Texas). This study protocol was reviewed and approved by the New York University Langone Health Institutional Review Board.

RESULTS

Descriptive statistics for the unmatched and matched samples are given in Table 1, and descriptive statistics by age subgroup are given in Web Tables 2–4. Prior to matching, children in NYCHA buildings tended to be older than children in other types of subsidized housing and were more likely to have a disability or to be blind. Children in NYCHA buildings were also more likely to be non-Hispanic Black and less likely to be non-Hispanic White or to have unknown race/ethnicity. Finally, the groups differed with regard to area-level characteristics. Children in the NYCHA sample were more likely to live in BBLs with a high-rise building ($\geq$7 floors) and to live in CBGs with a lower mean proportion of individuals aged 18–49 years, a higher proportion of individuals aged $\geq$50 years, a higher proportion of Black individuals, and a higher proportion of households with poverty:income ratios of $<$1.00 or 1.00–1.24. Population density was slightly higher in CBGs with other subsidized housing than in CBGs with NYCHA developments. These differences could reflect the fact that the "other subsidized housing" comparison category captures a relatively broad range of housing programs and a more heterogeneous group of households than the sample in NYCHA developments.

Table 2 shows monthly mean numbers of health-care visits per 1,000 children associated with each outcome condition in the pre- and postpolicy periods. Children in NYCHA developments tended to experience slightly higher encounter rates, with the most pronounced differences for asthma visits. In the prepolicy period, children in NYCHA developments experienced an average of 2.8 additional asthma-associated outpatient visits and 1.7 additional asthma-associated emergency department visits per 1,000 children each month, relative to children in the comparison group. Web Table 5 shows weighted counts of encounters for each condition before and after the policy was introduced. Rates for all outcomes in the prepolicy period (aggregated by quarter), which we used to assess the extent to which outcome trends were parallel between the groups, are plotted in Web Figures 1–3. Because this analysis was a longitudinal assessment of a fixed cohort, enrollment in Medicaid declined over time within our sample, and consequently visit rates tended to decline over time. Approximately 70% of the original cohort was enrolled in Medicaid at the end of the study period (Web Figure 4).

Table 3 shows DiD coefficient estimates associated with the treatment × time interaction for each health outcome in each care setting in fully adjusted models. We observed a statistically significant coefficient with regard to URIs in the outpatient setting (incidence rate ratio (IRR) = 1.05, 95% confidence interval (CI): 1.01, 1.08), which suggests that rates in the post–policy intervention period among children in NYCHA developments were slightly higher than would have been expected, given trends in the comparison group. We did not observe statistically significant associations for any other outcome.

Table 4 presents DiD coefficient estimates for each health outcome by age group. For outpatient URI visits, the point estimate was most pronounced among children aged 3–6 years at baseline (IRR = 1.08, 95% CI: 1.02, 1.15), although the estimate was also elevated among children aged 7–15 years (IRR = 1.05, 95% CI: 0.99, 1.11). Aside from outpatient URI visits among children aged 3–6 years, there were no other statistically significant associations between the policy and any of the other outcomes within any age stratum.

In addition to the main analysis, we assessed changes in rates of outcomes when restricting the analysis to child-months where a child was enrolled in Medicaid. Average monthly rates in the pre– and post–policy intervention periods under this scenario are shown in Web Table 6. DiD regression results were identical to those of the main analysis in sign and significance (Web Table 7). We also restricted the sample to children who were continuously enrolled in Medicaid throughout the study period (NYCHA: n = 43,695; comparison group: n = 22,817) and rematched on all variables previously described. DiD point estimates for the restricted cohort were directionally similar to those of the main analysis; however, no estimates reached statistical significance (Web Table 8). We fitted models using the primary diagnosis code to define outcomes, instead of any diagnosis code (Web Table 9). There was a significant positive association between the policy and rates of emergency department asthma visits (IRR = 1.13, 95% CI: 1.03, 1.25). We created a matched sample of children who did not move between BBLs during the study period (NYCHA: n = 50,061; comparison group: n = 29,146) and reran the analyses with this restricted sample (Web Table 10).

Table 1. Characteristics of Unmatched and Matched Samples of Medicaid-Enrolled Children Living in New York City Housing Authority Properties and in Other Subsidized Housing at Baseline (November 1, 2015), New York, New York[a]

Characteristic	Unmatched Sample			Matched Sample		
	NYCHA Group (n = 72,072)	Comparison Group (n = 108,780)	Standardized Difference	NYCHA Group (n = 71,114)	Comparison Group (n = 47,174)	Standardized Difference
Individual characteristics						
Age, years[b]	8.1	7.6	0.11	7.8	7.8	0.00
Age group (years), %						
≤2	18.2	21.8	−0.09	20.3	20.5	−0.01
3–6	24.9	25.9	−0.02	25.7	25.5	0.01
7–15	56.9	52.2	0.09	54.0	54.0	0.00
Female sex, %	49.0	48.8	0.00	49.0	49.0	0.00
Race/ethnicity, %						
Non-Hispanic White	4.2	8.0	−0.16	4.6	5.3	−0.03
Non-Hispanic Black	38.2	26.9	0.25	37.0	37.0	0.00
Hispanic	27.5	26.3	0.03	26.1	26.1	0.00
Non-Hispanic Asian	3.4	5.7	−0.11	3.5	3.5	0.00
Other	3.7	5.0	−0.06	4.4	4.4	0.00
Unknown	23.1	28.2	−0.12	24.4	23.7	0.02
Blind/disabled, %	9.6	5.0	0.18	8.9	8.9	0.00
Chronic medical condition, %	72.2	68.6	0.08	69.3	69.3	0.00
High-rise building (≥7 floors) in BBL, %	72.3	14.0	1.21	45.5	45.5	0.00
Duration of enrollment during prepolicy period, months	29.3	28.6	0.08	28.7	28.7	0.00
Block group characteristics						
Age group (years), %						
≤17	25.8	24.9	0.10	25.4	25.4	0.00
18–49	42.8	46.8	−0.47	44.0	44.0	0.00
≥50	31.4	28.3	0.31	30.6	30.6	0.00
Race/ethnicity, %						
Black	48.5	35.4	0.54	47.1	47.1	0.00
Hispanic	47.7	47.7	0.00	46.0	46.0	0.00
Poverty:income ratio, %						
<1.00	43.8	31.1	0.77	38.3	38.3	0.00
1.00–1.24	8.8	7.6	0.18	8.8	8.8	0.00
Population, no. of persons/m^2	0.04	0.04	−0.12	0.03	0.03	0.00

Abbreviations: BBL, borough-block-lot parcel; NYCHA, New York City Housing Authority.

[a] All characteristics were measured at baseline except for number of months enrolled during the pre–policy intervention period. The matched sample incorporated overlap weights.

[b] Values are expressed as mean.

Under this specification, the significant association between the policy and URI visits in the outpatient setting became marginally significant (IRR = 1.04, 95% CI: 1.00, 1.08; P = 0.067). Results from models incorporating a 3-month washout period following policy implementation were similar to the main model specification with regard to directionality and significance (Web Table 11). We did not find evidence of a significant association between the smoke-free policy and encounters for injuries (a negative control outcome) in either care setting (Web Table 12). When we specified August 2017–July 2018 as a placebo treatment year, estimates were directionally similar to those of the main analysis (with the exception of outpatient visits for LRI), though point estimates were attenuated (Web Table 13).

Table 2. Monthly Mean Numbers of Health-Care Visits for Respiratory Outcomes per 1,000 Children Before and After Implementation of a Smoke-Free Housing Policy in New York City Housing Authority Properties, New York, New York, 2015–2019

Health Outcome	Before No-Smoking Policy Intervention				After No-Smoking Policy Intervention			
	NYCHA Group		Comparison Group		NYCHA Group		Comparison Group	
	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI
Outpatient visits								
Asthma	27.5	27.2, 27.8	24.7	24.4, 25.0	23.9	23.5, 24.2	21.7	21.3, 22.1
LRI	3.8	3.7, 3.9	3.6	3.5, 3.7	2.3	2.1, 2.4	2.3	2.2, 2.4
URI	27.9	27.6, 28.2	27.7	27.3, 28.0	19.6	19.3, 20.0	18.6	18.3, 19.0
ED visits								
Asthma	7.1	6.9, 7.2	5.4	5.2, 5.5	7.9	7.7, 8.1	5.7	5.5, 5.9
LRI	1.4	1.4, 1.5	1.2	1.1, 1.3	1.3	1.2, 1.4	1.0	0.9, 1.1
URI	7.8	7.7, 7.9	6.5	6.4, 6.7	6.5	6.3, 6.7	5.2	5.0, 5.3

Abbreviations: CI, confidence interval; ED, emergency department; LRI, lower respiratory tract infection; NYCHA, New York City Housing Authority; URI, upper respiratory tract infection.

None of the associations in the pseudotreatment year were statistically significant.

DISCUSSION

Within a large matched sample of children in NYC, we did not find evidence that implementation of a smoke-free public housing policy was associated with a decrease in health-care encounters for SHS-sensitive conditions within the first 17 months postpolicy. While a growing body of evidence has evaluated smoke-free housing policies with regard to air quality, this analysis was among the first to examine associations with health outcomes. Our findings are consistent with a prior study of air quality in NYC which suggested that the smoke-free housing policy in NYCHA developments was not significantly associated with reductions in airborne nicotine after 1 year (19).

Table 3. Difference-in-Differences Incidence Rate Ratios Comparing Monthly Mean Numbers of Health-Care Visits for Respiratory Outcomes per 1,000 Children Between Children Living in New York City Housing Authority Properties and Children in Other Subsidized Housing (Matched Sample), New York, New York, 2015–2019[a]

Health Outcome	IRR	95% CI	*P* Value
Outpatient visits			
Asthma	0.99	0.94, 1.04	0.614
LRI	0.94	0.85, 1.03	0.195
URI	1.05	1.01, 1.08	0.007
ED visits			
Asthma	1.05	0.98, 1.13	0.143
LRI	1.12	0.98, 1.27	0.099
URI	1.05	0.99, 1.11	0.122

Abbreviations: CI, confidence interval; ED, emergency department; IRR, incidence rate ratio; LRI, lower respiratory tract infection; URI, upper respiratory tract infection.

[a] IRR estimates and *P* values correspond to the coefficient associated with treatment × time interaction in a negative binomial difference-in-differences regression model. Models included matching weights and controlled for age (years; continuous), age group (≤2, 3–6, or 7–15 years), sex, race/ethnicity, blindness/disability status, chronic conditions, presence of a high-rise building (≥7 floors) in the borough-block-lot parcel, season, and the census block group–level characteristics listed in Table 1.

Our findings may be explained, in part, by challenges associated with implementation of the smoke-free policy during the early rollout period. In a qualitative analysis of barriers to successful implementation of the NYCHA policy, Jiang et al. (35) noted perceptions among residents and staff that the policy overreached by prohibiting smoking in individual apartments, in addition to public areas. Other barriers to implementation included safety concerns with regard to challenging others' smoking behavior, as well as structural barriers to compliance (e.g., lacking a comfortable area in which to smoke outdoors) and a lack of smoking cessation resources. Many residents felt that the policy was unfairly singling out tobacco smokers in the context of widespread marijuana use, as well as other pressing housing-quality issues. The complexities associated with maintaining smoke-free policies in multifamily housing suggest the need for ongoing engagement between residents and housing managers to develop sustainable implementation strategies.

Rates of outpatient URI visits declined for both groups in the postpolicy period but were slightly higher among NYCHA residents than would be expected, given observed rates within the comparison group. Likewise, rates of emergency department asthma visits among children in NYCHA developments were elevated in the postpolicy period compared with the control group when we defined outcomes using primary diagnosis codes. We interpret these unexpected findings with caution, for several reasons. First, the

Table 4. Difference-in-Differences Incidence Rate Ratios Comparing Monthly Mean Numbers of Health-Care Visits for Respiratory Outcomes per 1,000 Children Between Children Living in New York City Housing Authority Properties and Children in Other Subsidized Housing, by Baseline Age Group (Matched Sample), New York, New York, 2015–2019[a]

Health Outcome	Baseline Age Group, years								
	≤2 (*n* = 23,524)			3–6 (*n* = 30,187)			7–15 (*n* = 64,577)		
	IRR	95% CI	*P* Value	IRR	95% CI	*P* Value	IRR	95% CI	*P* Value
Outpatient visits									
Asthma	0.96	0.83, 1.12	0.637	1.01	0.93, 1.09	0.882	0.99	0.93, 1.06	0.796
LRI	0.95	0.81, 1.11	0.520	0.89	0.75, 1.05	0.156	0.95	0.80, 1.14	0.591
URI	1.02	0.95, 1.08	0.619	1.08	1.02, 1.15	0.010	1.05	0.99, 1.11	0.080
ED visits									
Asthma	1.12	0.98,1.29	0.087	1.06	0.94, 1.20	0.338	1.01	0.91, 1.12	0.863
LRI	1.09	0.89, 1.33	0.412	1.11	0.88, 1.41	0.370	1.14	0.89, 1.45	0.311
URI	1.07	0.97, 1.19	0.174	1.05	0.94, 1.17	0.378	1.01	0.91, 1.11	0.878

Abbreviations: CI, confidence interval; ED, emergency department; IRR, incidence rate ratio; LRI, lower respiratory tract infection; URI, upper respiratory tract infection.

[a] IRR estimates and *P* values correspond to the coefficient associated with treatment × time interaction in a negative binomial difference-in-differences regression model. Models included matching weights and controlled for age (years; continuous), sex, race/ethnicity, blindness/disability status, chronic conditions, presence of a high-rise building (≥7 floors) in the borough-block-lot parcel, season, and the census block group–level characteristics listed in Table 1.

possibility of artifactual influences of residual confounding or selection bias cannot be ruled out. Second, IRRs were small in magnitude. For example, with regard to outpatient URIs, the change in the NYCHA group pre- and postpolicy was an average of −8.3 visits per 1,000 children per month, versus a change in the comparison group of −9.1 visits per 1,000 children per month. Consequently, the difference between the groups (comparing the pre- and postpolicy periods) was a relatively modest 0.8 visits per 1,000 children per month.

Nevertheless, although differences between the groups were small, the potential for adverse policy effects should be probed in future research. A prior study of public housing in Norfolk, Virginia, found that airborne nicotine and $PM_{2.5}$ levels declined immediately following the introduction of a smoke-free policy but increased beyond prepolicy levels 12 months after policy implementation (16). There is also limited evidence that other types of smoking restrictions—such as smoke-free laws in workplaces, restaurants, and bars—could be associated with displacing smoking from regulated environments into home environments (36, 37), though most studies have not observed such an association (37). It is possible that smoke-free housing policies could, in some cases, displace smoking behavior from common areas (where the policy is more likely to be enforced) into private apartments, despite the ban. This could lead to increased SHS exposure for children who live with residents who smoke.

Strengths of this study include leveraging the large population of residents in NYCHA and other subsidized housing developments in NYC to conduct a well-powered DiD analysis. We integrated hypothesized individual- and area-level confounding variables, incorporating demographic characteristics, aspects of the built environment, and CBG-level demographic and economic factors. We explored a number of model specifications to test the robustness of our findings to potential forms of confounding (e.g., examining a negative control outcome and pseudotreatment year) and differences in sample selection approaches (e.g., restricting the sample to continuously enrolled children).

This study also had a number of limitations. Although average enrollment within groups was very similar over time, it is possible that the drivers of attrition differed between groups, which could have affected estimates. While we visually inspected outcome trends in the prepolicy period, the counterfactual assumption underlying the DiD analysis is not empirically testable. Even though other types of subsidized housing developments were not required by the HUD rule to implement smoke-free policies, it is possible that some children in our comparison sample lived in developments that had independently instituted smoking restrictions. These policies could dilute observed associations between the NYCHA policy and health outcomes, particularly if they were implemented during the study period. Furthermore, while we selected children for the comparison group from BBLs that contained other types of subsidized housing, comparison BBLs were heterogeneous and often contained mixed-income housing. It is possible that children in the comparison group differed from children in NYCHA developments on the basis of both individual factors (e.g., aspects of socioeconomic status) and built environment factors (e.g., building age and maintenance history) that were not addressed in this study. In the context of a DiD analysis, these factors would also have to be associated with outcome trends (rather than outcome levels) to result in confounding (30). Finally, we had limited postintervention data with which to examine time-varying associations. This is an area for future research, given prior evidence of differential impacts of smoke-free policies on air quality over time (16).

Addressing the high levels of SHS exposure in multifamily housing remains a priority, as a substantial body of literature has highlighted disparities in respiratory health outcomes across housing environments (23, 24, 38). In this large, quasi-experimental study, we did not find evidence that smoke-free policies introduced in NYC public housing developments were associated with attributable decreases in health-care encounters for SHS-sensitive conditions among children during the first 17 months after policy implementation. We found suggestive evidence that the policy was instead associated with relatively higher levels of health-care encounters than would be expected, although these findings were not consistent across model specifications. Ongoing monitoring of smoke-free housing policies over time will be essential to elucidating the potential impact of these policies on patterns of SHS exposure and attributable health outcomes. Most importantly, additional efforts to support policy enforcement, provide smoking cessation services, and raise awareness of the health benefits of reduced SHS exposure in home settings are needed. Strategies for improving smoke-free housing policy effectiveness may include providing more support for smokers to quit, further engaging residents in implementation, and investing to improve the environmental and structural health of buildings as part of a wider healthy-homes policy agenda.

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