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Brief Report

Long-Term Trends in Secondhand Smoke Exposure in High-Rise Housing Serving Low-Income Residents in New York City: Three-Year Evaluation of a Federal Smoking Ban in Public Housing, 2018–2021

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Abstract

Introduction: In July 2018, the U.S. Department of Housing and Urban Development passed a rule requiring public housing authorities to implement smoke-free housing (SFH) policies. We measured secondhand smoke (SHS) exposure immediately before, and repeatedly up to 36 months post-SFH policy implementation in a purposeful sample of 21 New York City (NYC) high-rise buildings (>15 floors): 10 NYC Housing Authority (NYCHA) buildings subject to the policy and 11 privately managed buildings in which most residents received housing vouchers (herein "Section 8").

Aims and Methods: We invited participants from nonsmoking households (NYCHA n = 157, Section-8 n = 118) to enroll in a longitudinal air monitoring study, measuring (1) nicotine concentration with passive, bisulfate-coated filters, and (2) particulate matter ($PM_{2.5}$) with low-cost particle sensors. We also measured nicotine concentrations and counted cigarette butts in common areas (n = 91 stairwells and hallways). We repeated air monitoring sessions in households and common areas every 6 months, totaling six post-policy sessions.

Results: After 3 years, we observed larger declines in nicotine concentration in NYCHA hallways than in Section-8, [difference-in-difference (DID) = −1.92 μg/m^3 (95% CI −2.98, −0.87), $p = .001$]. In stairwells, nicotine concentration declines were larger in NYCHA buildings, but the differences were not statistically significant [DID= −1.10 μg/m^3 (95% CI −2.40, 0.18), $p = .089$]. In households, there was no differential change in nicotine concentration (p = .093) or in $PM_{2.5}$ levels (p = .385).

Conclusions: Nicotine concentration reductions in NYCHA common areas over 3 years may be attributable to the SFH policy, reflecting its gradual implementation over this time.

Implications: Continued air monitoring over multiple years has demonstrated that SHS exposure may be declining more rapidly in NYCHA common areas as a result of SFH policy adherence. This may have positive implications for improved health outcomes among those living in public housing, but additional tracking of air quality and studies of health outcomes are needed. Ongoing efforts by NYCHA to integrate the SFH policy into wider healthier-homes initiatives may increase policy compliance.

Introduction

Secondhand smoke (SHS) exposure is one of the leading causes of premature death in the United States and is attributable to nearly 34 000 deaths among nonsmokers.[1–3] According to reports from the U.S. Surgeon General's Office, 2.5 million nonsmoking adults have died from SHS exposure since 1964.[1,3] Exposure to SHS is linked to numerous health problems in infants and children, including more frequent and severe asthma attacks, respiratory infections, ear infections, and sudden infant death syndrome.[4–7] While many communities and states have adopted smoke-free laws within public places such as worksites, bars, and restaurants, those living within multiunit housing are at risk of involuntary SHS exposure at home.[4,6–8]

The U.S. Department of Housing and Urban Development (HUD) passed a rule effective July 2018 requiring all public housing authorities (PHAs) to implement smoke-free housing (SFH) policies in their developments, prohibiting residents

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from smoking within their residences, common areas (i.e. lobbies, elevators, stairwells, and hallways), and a 25-foot perimeter of all developments.[9,10] A few studies have prospectively evaluated policies aimed at reducing SHS exposure by prohibiting smoking within multi-unit housing, but due to limitations in sample size and follow-up duration, results are inconclusive.[11–13]

Previously, we reported changes in air quality from pre-to-12 months post-SFH policy implementation in a large sample of nonsmoking households and common areas of 10 high-rise New York City Housing Authority buildings (NYCHA), and contrasted the 1-year longitudinal findings with a comparison group of 11 private sector buildings of comparable size and population make-up (section-8 buildings).[14] At that time, we found no differential change in SHS in NYCHA buildings compared to the matched private buildings, using objective air quality measures of air nicotine concentration and particulate matter less than 2.5 μm diameter ($PM_{2.5}$). Since then, we have continued to evaluate the impact of SFH policy on SHS exposure and health outcomes. We present here air quality trajectory findings up to 36 months post-SFH policy implementation in all 21 NYCHA and comparison buildings as an evaluation of the long-term impact of SFH policy on SHS exposure.

Methods

Study Population

As described in detail elsewhere, for this quasi-experimental study we selected a purposeful sample of 21 high-rise buildings located in upper Manhattan and the Bronx, including 10 NYCHA buildings subject to the SFH policy and 11 section-8 buildings with no defined SFH policies. The following building eligibility criteria, based on the NYCHA Tenant Data System, were established to maximize homogeneity between groups: (1) high-rise buildings (>15 floors), (2) large resident population (>150 units), (3) at least 80% of the resident population were Black or Hispanic individuals, and (4) at least 20% of the resident population was younger than 18 years.[15]

Study Design and Procedures

We conducted a baseline telephone survey, with mop-up "door-to-door" efforts, to assess smoking prevalence and experience with SHS incursions immediately before the policy went into effect. We found the NYCHA and section-8 settings to be comparable in sociodemographic characteristics (i.e. language spoken and the number of minor-aged children in the home), cigarette smoking behaviors, and self-reported secondhand smoke measures. Detailed information on the study design, recruitment, and comparability of arms can be found elsewhere.[15] We invited a volunteer sample of 275 nonsmoking households (NYCHA n = 157; Section-8 n = 118) to enroll in the longitudinal air monitoring study. In each setting, we measured air quality for a period of 7 days at 6-month intervals. Twelve households were excluded from the analysis based on evidence of indoor smoking or incomplete air quality data at baseline, for an initial analytic sample of 263 nonsmoking households (NYCHA n=153; section-8 n = 110). Of the 263 households enrolled at baseline, an additional 19 households moved out of the air monitoring sampling buildings, which resulted in an analytic sample of 244 households assessed in this study (NYCHA n = 139; Section-8 n = 105).

We completed a total of six post-policy sessions: From 6 months (December 2018–March 2019) to 36 months post-policy (May–September 2021). We prematurely stopped data collection at the end of the third post-policy session at 18 months (December 2019–March 2020) because of COVID-19 pandemic restrictions but resumed air monitoring in common areas at 24 months (April–September 2020) and in nonsmoking households at 30 months (December 2020–March 2021). We completed air monitoring 36 months after the policy in 189 of the 244 households, for a 3-year response rate of 77.5%. We also monitored air quality in two randomly selected hallways and two randomly selected stairwells per building for a period of 7 days for each wave (NYCHA n = 45 measurements; section-8 n = 46 measurements).

Objective Air Quality Measures

The primary objective air quality measure was airborne nicotine, measured over a period of 7 days using passive, bisulfate-coated filters that were placed in the living rooms of enrolled nonsmoking households and common areas (stairwells and hallways). Filters were prepared and analyzed at Johns Hopkins University Bloomberg School of Public Health using the school's Secondhand Smoke Exposure Assessment Laboratory standard operating procedures. The nicotine level of detection (LOD) for 7-day samples was 0.017μg/m^3. Our secondary and tertiary measures were: (1) indoor $PM_{2.5}$ levels, obtained in households only using calibrated low-cost AirBeam particle sensors (HabitMap), and (2) mean cigarette butt counts in common areas obtained twice per wave in four randomly selected hallways and 2 randomly selected stairwells in the bottom 10 floors per building. We performed additional statistical analyses to review the distribution of PM 2.5 values in our selected sample. The distribution of values followed a normal distribution, which strengthened our decision to report mean values for PM 2.5. Detailed information on the study methods is described elsewhere.[15]

Statistical Analysis

We calculated air nicotine geometric means and estimated the percentage of filters with levels of detectable nicotine. Estimates were computed separately for nonsmoking households and common areas (stairwells and hallways). We calculated indoor $PM_{2.5}$ means and the percentage of readings with levels greater than the Environmental Protection Agency annual health standard of 12.0 μg/m^3.[16] Finally, we calculated cigarette butt count means, separately for stairwells and hallways. We plotted the long-term trends in airborne nicotine concentrations with 95% CI for each wave of data collection, from pre-policy to 36 months post-policy implementation.

We used a difference-in-difference (DID) approach to compare within-group changes in air quality between NYCHA and section-8 buildings from pre-policy to 36 months after SFH policy implementation using a mixed linear regression model for the three measures of interest (air nicotine, indoor $PM_{2.5}$, and cigarette butt counts). We modeled our air nicotine outcome by taking the natural log of the original nicotine concentration to account for skewness. All regression models included fixed effects for the study arm (NYCHA vs. section-8), data collection wave (pre-policy and subsequent six waves after policy implementation), and their interaction. We adjusted for clustering of units nested within buildings and repeated measurements over time. The DID estimates compared the magnitude of within-group change in NYCHA

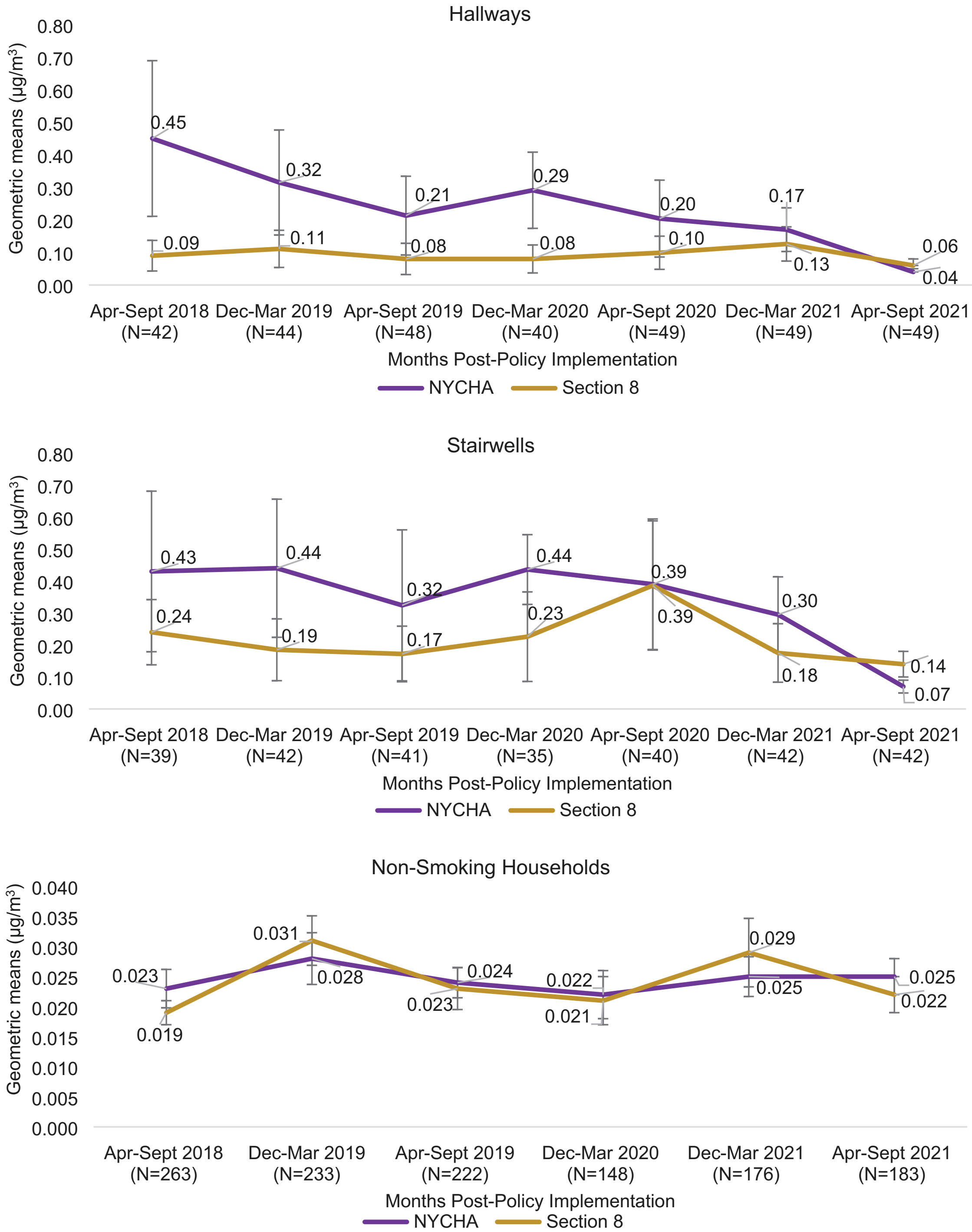

Figure 1. Change in air nicotine levels from pre-policy to three years post-SFH policy implementation in two low-income, subsidized housing settings in NYC, 2018–2021.

versus section-8 buildings at 36 months. Exact *p*-values were reported, where $\alpha = 0.05$, using a 2-sided test. All analyses were performed using SAS statistical software, version 9.4 (SAS Institute).

Results

Immediately prior to the SFH policy going into effect, airborne nicotine and indoor $PM_{2.5}$ concentrations were higher in NYCHA buildings compared to section-8 (Figure 1, Supplementary Table 1). Nicotine was detected in nearly all NYCHA hallways (89.5%) and stairwells (94.7%), but only in 13.1% of nonsmoking households.[14,17] In summer 2021, 36 months after policy implementation, nicotine concentrations remained higher in NYCHA settings for nonsmoking households but had declined more rapidly in both common areas compared to section-8 (Figure 1).

In NYCHA common areas, differential reductions in air nicotine compared with similar settings in section-8 were attributed to SFH policy (Table 1). In households, temporal changes in air nicotine were similar between NYCHA and section-8 settings. In contrast, the magnitude of differential change in air nicotine was significantly larger in NYCHA hallways [DID= −1.92 μg/m^3 (95% CI −2.98, −0.87), *p* = *.001*]. Of note, air nicotine dropped consistently in NYCHA hallways from pre-policy [0.43(0.11) μg/m^3] through 36 months post-policy [0.04(0.01) μg/m^3]. In stairwells, decreases in air nicotine were larger in NYCHA buildings [DID= −1.10 μg/m^3 (95% CI −2.40, 0.18), *p* = *.089*], but the differences were not statistically significant or consistent throughout assessment time. Notable declines in air nicotine in NYCHA stairwells occurred from 24 months post-policy [0.39(0.12) μg/m^3] through 36 months post-policy [0.07(0.02) μg/m^3]. There was no differential change in indoor $PM_{2.5}$ levels for nonsmoking households between comparison groups, although we observed slightly larger declines in section-8 (**Supplementary Table 1**). Likewise, differential change in variability in average cigarette butt counts in stairwells and hallways was also not statistically significant.

Discussion:

This long-term analysis stems from a larger-scale natural experiment designed to evaluate whether a federal policy to ban smoking in PHA buildings is associated with improvement in air quality and reductions in tobacco-related health outcomes over time. Our findings presented here suggest that levels declined differentially in NYCHA common areas (stairwells and hallways) 3 years after policy introduction compared to section-8 buildings, where levels of detectable nicotine were high. In contrast, we found no differential change in levels of air nicotine observed in NYCHA nonsmoking households compared with nonsmoking households in section-8 buildings, where levels were substantially lower at baseline. Overall, results suggest that NYCHA residents might be smoking less frequently in common areas, particularly in more visible areas such as hallways. It is plausible that these declines may be attributable to SFH policy. Evidence accrued over three years suggests that resident indoor smoking behaviors change slowly after policy implementation, as these differences were not detected in our first published results on 1-year post-policy effects. Continued assessment can confirm whether these reductions continue their downward trajectories, potentially because of increased adherence to the SFH policy, or whether results plateau over time.

To the best of our knowledge, this is one of the few long-term prospective studies to empirically evaluate the association between SHS exposure and SFH policy using objective air quality measures such as airborne nicotine and indoor $PM_{2.5}$. Previous studies have evaluated the immediate consequences of HUD policy, or other voluntary SFH policies that were adopted within PHAs,[11–13] but to the best of our knowledge evidence of reduced SHS exposure over multiple years has not been evaluated. While modest reductions in air nicotine levels were observed in NYCHA versus section-8 common areas over time in this study, we cannot rule out the possibility this may be because of the chance. It is, however, noteworthy that NYCHA management has scaled up community engagement and enforcement over time, with the strongest efforts occurring in 2020 onward (**Supplementary Figure 1**). Across all developments, over 8500 signs have been installed and beginning from 2020, cessation working groups and SFH liaison programs were launched and have scaled citywide. To date, no evictions have occurred. Instead, cessation teams

Table 1. Difference-in-Difference Model Results for Change in Air Quality Measures From Before to 36 Months Post-SFH Policy Implementation Across Two Low-Income Subsidized Housing Settings in NYC.

Effect	Mean difference (μg/m^3) Pre-policy to 36 months post-policy MD (95% CI)	Difference-in-difference estimate (μg/m^3) (95% CI)	*p*-Value
Airborne nicotine concentration			
Stairwells			
NYCHA	−1.78 (−2.71, −0.84)	−1.10 (−2.40, 0.18)	*.089*
Section-8	−0.67 (−1.56, 0.22)		
Hallways			
NYCHA	−2.37 (−3.14, −1.60)	−1.92 (−2.98, −0.87)	*.001*
Section-8	−0.44 (−1.16, 0.28)		
Apartments			
NYCHA	0.18 (−0.05, 0.41)	0.31 (−0.05, 0.67)	*.093*
Section-8	−0.13 (−0.40, 0.14)		
Indoor particulate matter2.5			
Apartments			
NYCHA	−5.80 (−8.28, −3.32)	1.70 (−2.15, 5.54)	*.385*
Section-8	−7.50 (−10.45, −4.55)		
Cigarette butt counts			
Stairwells			
NYCHA	1.95 (−4.46, 8.36)	3.40 (−5.45, 12.26)	*.431*
Section-8	−1.45 (−7.57, 4.66)		
Hallways			
NYCHA	−0.55 (−2.83, 1.73)	0.31 (−2.83, 3.47)	*.843*
Section-8	−0.86 (−3.04, 1.31)		

have conducted outreach to nearly 200 households with policy violations. Ongoing evaluation of air quality and health outcomes is needed to continue to ascertain the potential effects of active implementation of SFH policies at reducing indoor SHS exposure, as well as to identify barriers to implementation.[18]

Our analysis has limitations. First, buildings were purposely selected for air monitoring and were not randomly chosen, which might limit the generalizability of findings to all NYC public housing buildings, as well as PHA elsewhere. Building criteria were determined *apriori* with consultation from NYCHA managers, incorporating factors likely to affect recruitment or longitudinal air quality monitoring. Second, air quality monitoring equipment is subject to variability. To account for variability within devices used to measure indoor $PM_{2.5}$, we calibrated all low-cost particle sensors before each sampling wave using cigarette smoke. Evidence supports that $PM_{2.5}$ is a valid surrogate of changes to indoor smoking along with airborne nicotine, which has been extensively validated to detect SHS.[13,19,20] Third, there is potential for indoor air quality measurements to be impacted by seasonality, with upward trends occurring during the winter months. However, employing a quasi-experimental design over 3 years, where data collection across both NYCHA and section-8 settings was matched by season, supports robust methods to account for seasonality in $PM_{2.5}$. Fourth, our DID analysis only accounts for one pre-policy wave of data collection, which might limit the ability to verify parallel trends assumption in comparison groups before the policy goes into effect.

Conclusion

These findings suggest that in its third year as implementation efforts have increased, a federally funded SFH policy applied to PHA may be effective at reducing SES exposure in common areas, with the most pronounced effects in hallways. HUD SFH policy was not, however, associated with reduced indoor air nicotine levels in households. The findings also suggest that continued efforts in community engagement and policy enforcement are needed for optimal policy effectiveness.

Supplementary Material

A Contributorship Form detailing each author's specific involvement with this content, as well as any supplementary data, are available online at https://academic.oup.com/ntr.

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Declaration of Interest

The authors have no competing interests to disclose at this time.

Institutional Review Board Statement: The study was approved by the New York University Grossman School of Medicine's Institutional Review Board (i17-00968, approved 29 August 2017).

Data Availability

All relevant data is contained within the article.

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Author Contributions

Conceptualization LET, TG, EA; Methodology LET, EA, TG, KW; Data Curation EA EG AT; Formal analysis EA KW; Funding Acquisition LET DS; Supervision LET DS TG KW; Visualization EA LET TG; Writing-original draft EA LET TG; Writing-review and edit, all authors; All authors have read and agreed to the published version of the manuscript.

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