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Brief Report
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Increases in Secondhand Smoke After Going Smoke-Free: An Assessment of the Impact of a Mandated Smoke-Free Housing Policy

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Abstract

Objective: The 12-month impact of federally mandated smoke-free housing (SFH) policy adoption (July 2018) was assessed using two markers of ambient secondhand smoke (SHS): airborne nicotine and particulate matter at the 2.5-micrometer threshold ($PM_{2.5}$).
Methods: We measured markers of SHS in Norfolk, VA from December 2017 to December 2018 in six federally subsidized multi-unit public housing buildings. Multi-level regression was used to model the following comparisons: (1) the month immediately before SFH implementation versus the month immediately after, and (2) December 2017 versus December 2018.
Results: There was a 27% reduction in indoor $PM_{2.5}$ and a 32% reduction in airborne nicotine in the first month after SFH adoption, compared to the month prior to adoption. However, there was a 33% increase in $PM_{2.5}$ and a 25% increase in airborne nicotine after 12 months.
Conclusions: US Department of Housing and Urban Development (HUD)-mandated SFH can reduce SHS in multi-unit housing. However, SFH could also plausibly increase indoor smoking. Policy approaches adopted by individual properties or housing authorities—for example, property-wide bans versus allowing designated smoking areas—could be driving this potential unintended consequence.
Implications: Successful implementation of SFH by public housing authorities in response to the HUD rule requires ongoing attention to implementation strategies. In this sense, SFH likely differs from other policies that might be seen as less intrusive. Long-term success of SFH will depend on careful policy implementation, including plans to educate and support housing authority staff, inform and engage residents, and build effective partnerships with community agencies.

Introduction

To reduce public housing residents' chronic exposure to secondhand smoke (SHS), the US Department of Housing and Urban Development (HUD) mandated that all US public housing adopt a smoke-free rule by July 31, 2018. HUD's rule requires that public housing authorities implement policies that: (1) prohibit lit tobacco products inside all dwelling units, indoor common areas, and housing authority administrative office buildings, and (2) limit smoking to at least 25 feet away from all housing and administrative buildings. Additionally, housing authorities can establish designated smoking areas outside the required 25-foot perimeter, which can include partially enclosed structures, or make their entire grounds smoke-free.[1–3]

There is extensive evidence for the potential of smoke-free housing (SFH) to positively affect health.[4] However, this has been based on early adopters of SFH—no work to date has assessed changes in indoor air quality after SFH implementation in response to HUD's rule. To understand whether adoption of SFH improves indoor air quality over a 12-month period, we measured two validated environmental markers for ambient SHS: (1) active sampling of particulate matter at the 2.5-micrometer threshold ($PM_{2.5}$),[5] and (2) passive sampling of airborne nicotine.[5–7]

Methods

Air quality monitoring was conducted in six multi-unit public housing buildings (one monitor per building) in Norfolk, VA from December 2017 to December 2018. Sites were mid-rise apartment buildings ranging between 47 and 114 units (87 units on average). Monitor location was chosen to maximize comparability between buildings (eg, not in direct airflow of HVAC system, similar distance from vents). Two of the six buildings were made smoke-free in January 2018, three were made smoke-free in July 2018, and another one was never made smoke-free due to having been converted to a Project-Based Section 8 property, which is not covered by HUD's rule. Particulate matter of 2.5 microns or lower ($PM_{2.5}$) was measured hourly over the entire monitoring period (December 2017–December 2018) using SidePak AM520 aerosol monitors (TSI, Inc., St. Paul, MN). SidePaks were installed in indoor common areas of each building, with a flow rate set to 1.7 L/min. A calibration factor of 0.32 was applied to yield measurements appropriate for SHS particles.[8,9] Data, expressed as μg/m^3, were downloaded twice weekly, at which time the monitors were also cleaned and zero-calibrated.

Airborne nicotine was measured using passive diffusion monitors[6] co-located with the SidePak monitors. The diffusion monitors collected vapor-phase nicotine onto a 37-mm polystyrene filter treated with sodium bisulfate encased in a sampling cassette. A diffusion screen allows air to pass through at a constant rate. The filters were deployed for 1 week during each measurement period, after which they were shipped to the University of California, Berkeley for gas chromatography analysis of the concentration of nicotine (μg/m^3) exposed to the filter. Blank and duplicate monitors were used for quality control.

We modeled two series of comparisons for both average daily $PM_{2.5}$ and airborne nicotine: (1) from the month immediately before SFH implementation compared to the month immediately after SFH, and (2) December 2017 compared to December 2018. The goal of the 1-month pre- and post-SFH analyses was to assess any immediate change in response to SFH. The goal of the 12-month December 2017 versus December 2018 comparison was to estimate the longer-term impact of SFH by comparing the last month in which all sites allowed smoking to the same month in the subsequent year.

Linear mixed modeling was used for all analyses. All models included random building and time effects (date for $PM_{2.5}$ analyses and month or year for airborne nicotine). The Project-Based Section 8 property on which smoking was never banned was included as a control. The complete modeling procedure is described in detail in Supplementary Material. Version 3.4.4 of R was used for all analyses.[10]

Results

Across all six sites, $PM_{2.5}$ ranged from 2.01 to 68.23 μg/m^3; airborne nicotine ranged from the lower limit of detection (0.021) to 1.48 μg/m^3 (see the Supplementary Material for full summary statistics). Table 1 displays unadjusted $PM_{2.5}$ and airborne nicotine for each comparison period. $PM_{2.5}$ and nicotine decreased in the month following SFH implementation, compared to the month immediately prior (−27% and −32%, respectively). Conversely, $PM_{2.5}$ and nicotine were both higher compared to the same month in the previous year (33% and 25%, respectively).

In our regression models, SFH was associated with decreases of 7.23 μg/m^3 of $PM_{2.5}$ and 0.23 μg/m^3 of airborne nicotine in the month immediately following implementation (Table 1; see Supplementary Material for full model estimates). We estimated a 7.87 μg/m^3 increase in $PM_{2.5}$ in December 2018, relative to the same month in the previous year (ie, before SFH in both the early- and later-adopting sites). We also estimated a 0.10 μg/m^3 increase in airborne nicotine, although the confidence interval for that estimate included zero.

Discussion

The 1-month pre- and post-assessment of SHS strongly suggests that there was a period of initial resident compliance with SFH. However, our results also suggest that SFH could potentially lead to lower compliance in the longer term, as indicated by increased indoor smoking. This seems counterintuitive, but could be plausible if residents are motivated to avoid punishment or minimize inconvenience, rather than by a sense of obligation to comply with SFH per se. Qualitative studies of housing authorities that were early adopters of SFH support this interpretation. For example, smokers who had previously smoked outside in courtyards or balconies reported that they started smoking indoors after SFH, with many describing going to great lengths to hide their smoking from housing authority staff (eg, by sitting near a bathroom vent).[11] In another study, property managers described how a lack of resources and difficulty establishing proof of smoking had led to minimal effort intervening against smoking

Table 1. Average Daily Indoor $PM_{2.5}$ and Airborne Nicotine by Comparison and Adjusted Change in Mean Daily $PM_{2.5}$ and Airborne Nicotine Following SFH Implementation in Norfolk, VA

	Observed pre-SFH air quality		Observed post-SFH air quality		Adjusted change (95% CI)	
Comparison	$PM_{2.5}$ (μg/m^3)	Nicotine (μg/m^3)	$PM_{2.5}$ (μg/m^3)	Nicotine (μg/m^3)	$PM_{2.5}$ (μg/m^3)	Nicotine (μg/m^3)
One month pre- and post-SFH	27.48	0.31	19.94	0.21	−7.23 (−8.98, −5.49)	−0.23 (−0.43, −0.04)
December 2017 vs. December 2018	18.92	0.36	25.18	0.45	7.87 (5.45, 10.28)	0.10 (0.00, 0.19)

CI = confidence interval. Observed values reflect measurements taken in common areas of five midrise buildings that implemented SFH in response to the HUD rule. Adjusted change in $PM_{2.5}$ and nicotine were estimated using linear mixed modeling with random site and time effects and included an additional building that did not implement SFH as a control.

taking place inside residents' apartments, instead choosing to focus on enforcing SFH in common areas.[12]

Our study has several limitations. First, any causal mechanism involved in the longer-term increase in indoor SHS after SFH can only be speculated upon. Future research should specifically address the role of punishment avoidance in residents' compliance with SFH. Other potential explanations should also be studied, including: how housing authorities engage with residents; changes in SFH enforcement over time; available resources to support resident smoking cessation; and the impact of resident turnover. The most statistically powerful analyses use $PM_{2.5}$, a proxy measure of SHS. However, the assumption that $PM_{2.5}$ is a valid index of changes in indoor smoking is supported by findings with airborne nicotine, which is highly specific to SHS. SFH policies can differ substantially between housing authorities, and thus our results could be driven by atypical SFH policy features and implementation strategies, which could limit generalizability. Finally, while we have attempted to control for seasonality, the nature of our design imposes limitations. Having multiple years of data would support more robust methods (eg, time series analyses) that could explicitly quantify seasonality in $PM_{2.5}$.

These findings suggest that SFH, in response to the HUD rule, has the potential to significantly reduce SHS in multi-unit low-income housing. However, SFH could have the unintended consequence of increasing indoor smoking. This may occur because residents opt to avoid punishment by smoking in their units rather than outdoors where their noncompliant behavior is more visible. However, this explanation requires confirmation through further investigation. With the recognition that simple *adoption* of SFH may not be sufficient, research is needed to identify best practice *implementation* approaches to optimize the long-term success of SFH policies. Implementation science—the study of methods to promote translation of research into practice—can generate evidence-based methods and tools to increase resident knowledge and support for SFH, increase resident compliance and enhance the effectiveness of enforcement strategies.[13] Applying these principles to SFH may provide an understanding about the degree to which differences in implementation approaches—such as how imposing a property-wide ban versus allowing designated outdoor smoking areas within the property boundary—can influence resident compliance.

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 Interests

None declared.

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