JOHNS HOPKINS
MEDICINE

Pulmonary Disease Associated with Fine Particulate Matter in Indoor Environments and Disparities in Economically Challenged Communities

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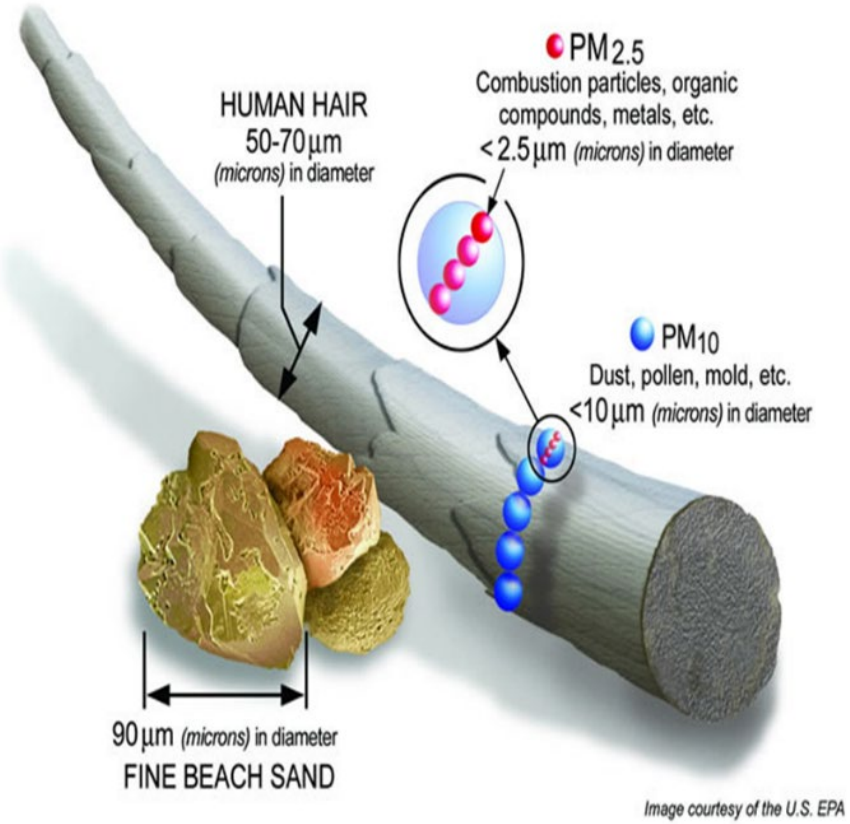
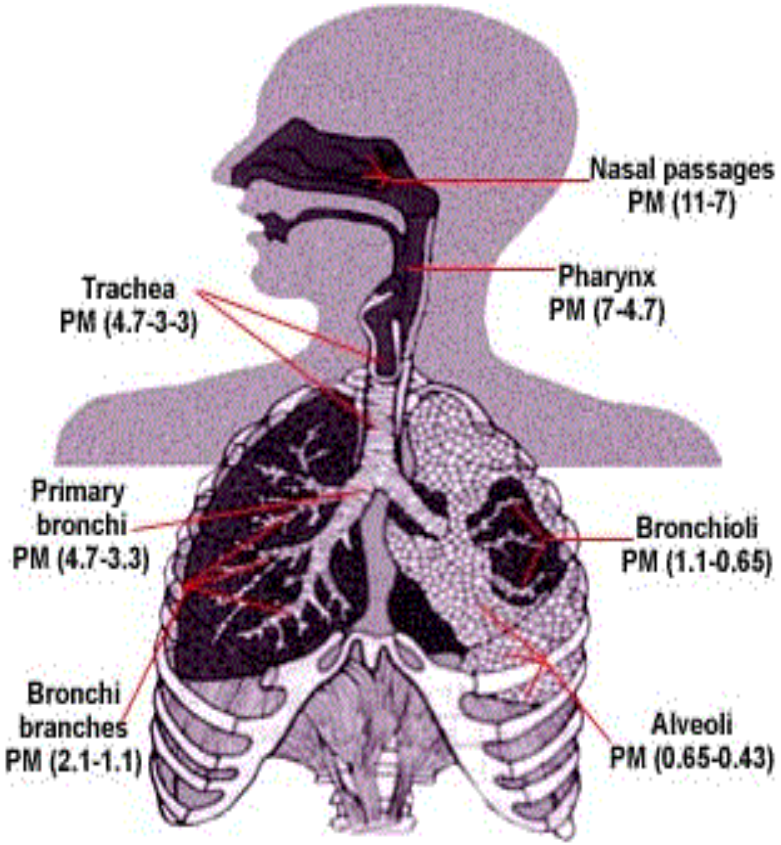
Associate Professor
April 21, 2021

Disclosures

- Royalties from UpToDate
- Consulting for Aridis
- Medical Education for Talem Health and Project Echo

Particulate Matter

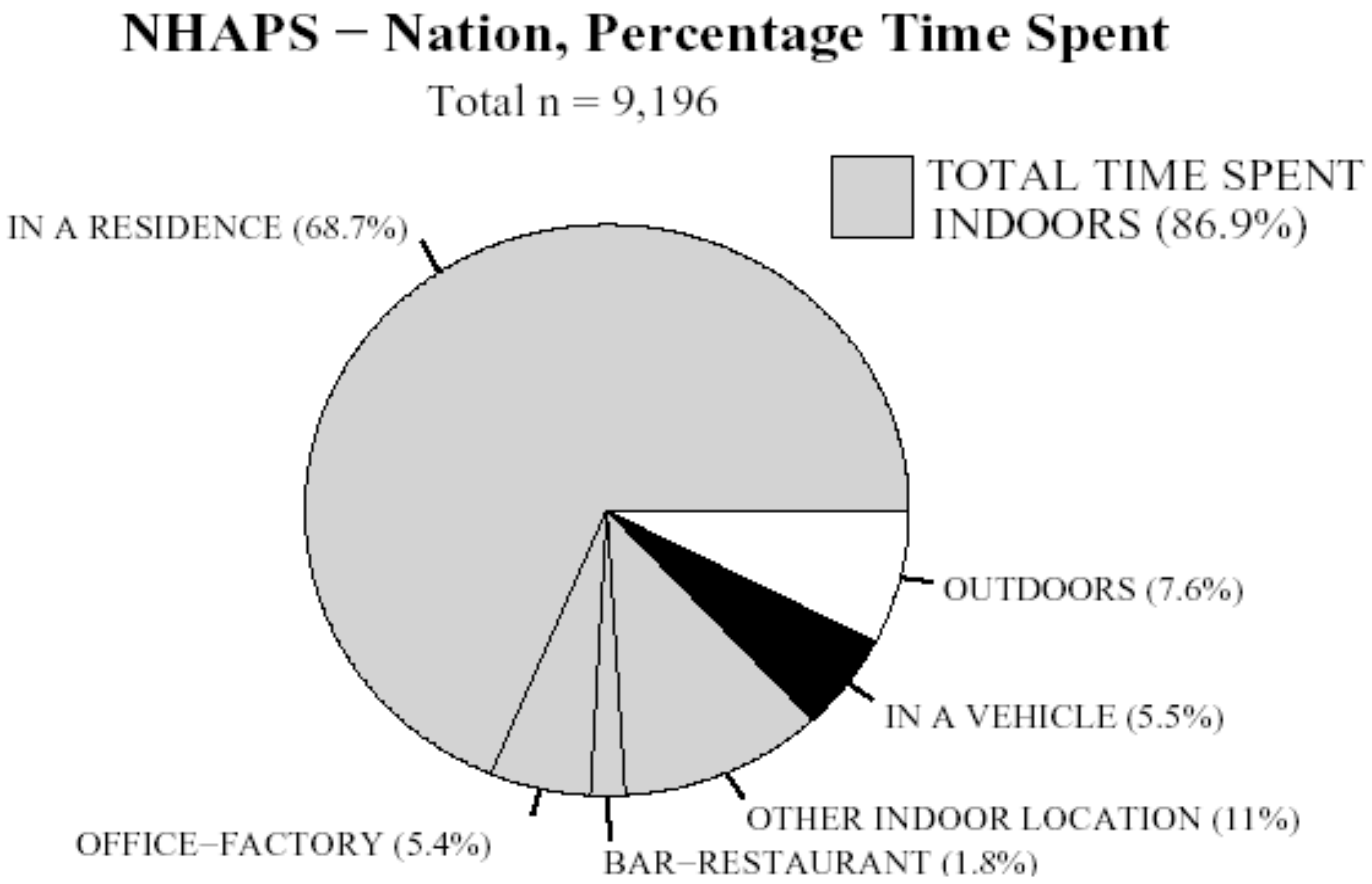




https://www.airnow.gov/index.cfm?action=aqibasics.particle

Disposition of Particulate Matter (PM) in the Respiratory system (Richard Wilson, Harvard Press, 1996)

Importance of Indoor Environment



Klepeis, NE et al. (2001). The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. *Journal of Exposure Science & Environmental Epidemiology*, *11*(3), 231-252.

Center for Childhood Asthma in the Urban Environment

Indoor Air and Childhood Asthma

* Co-Funded by EPA and NIEHS

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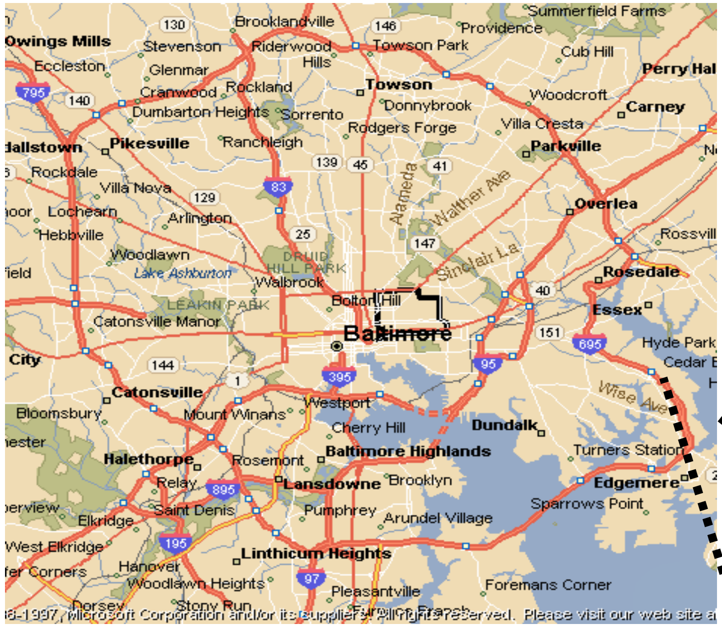
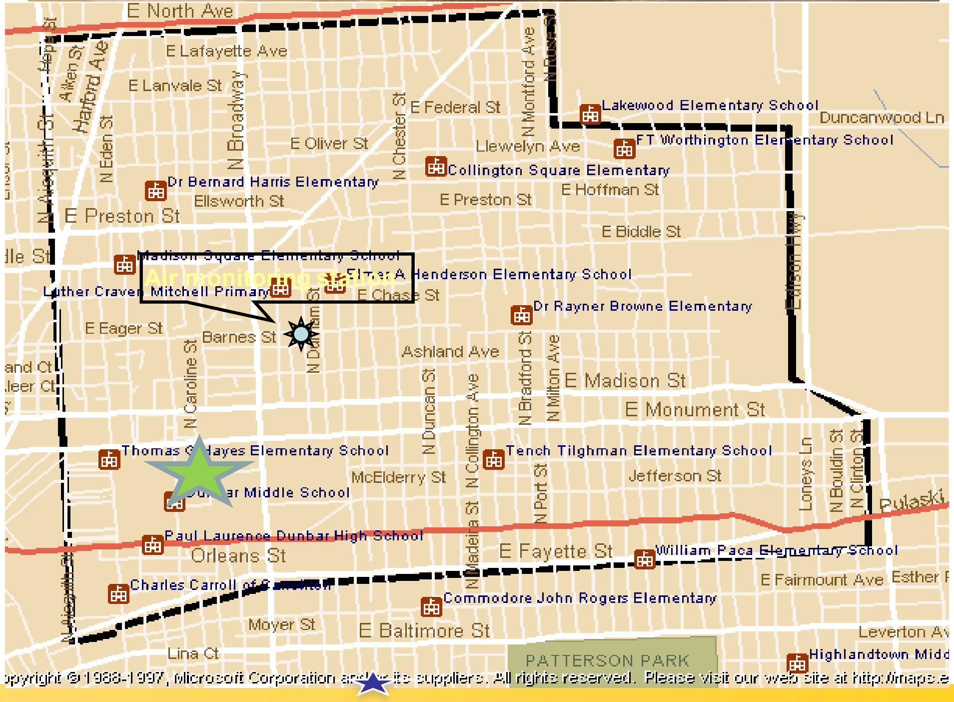
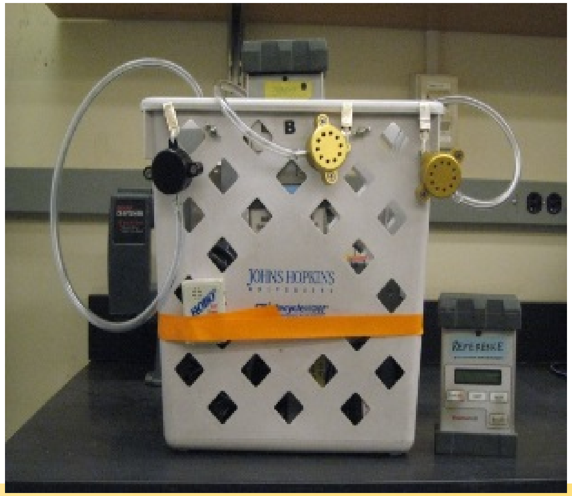
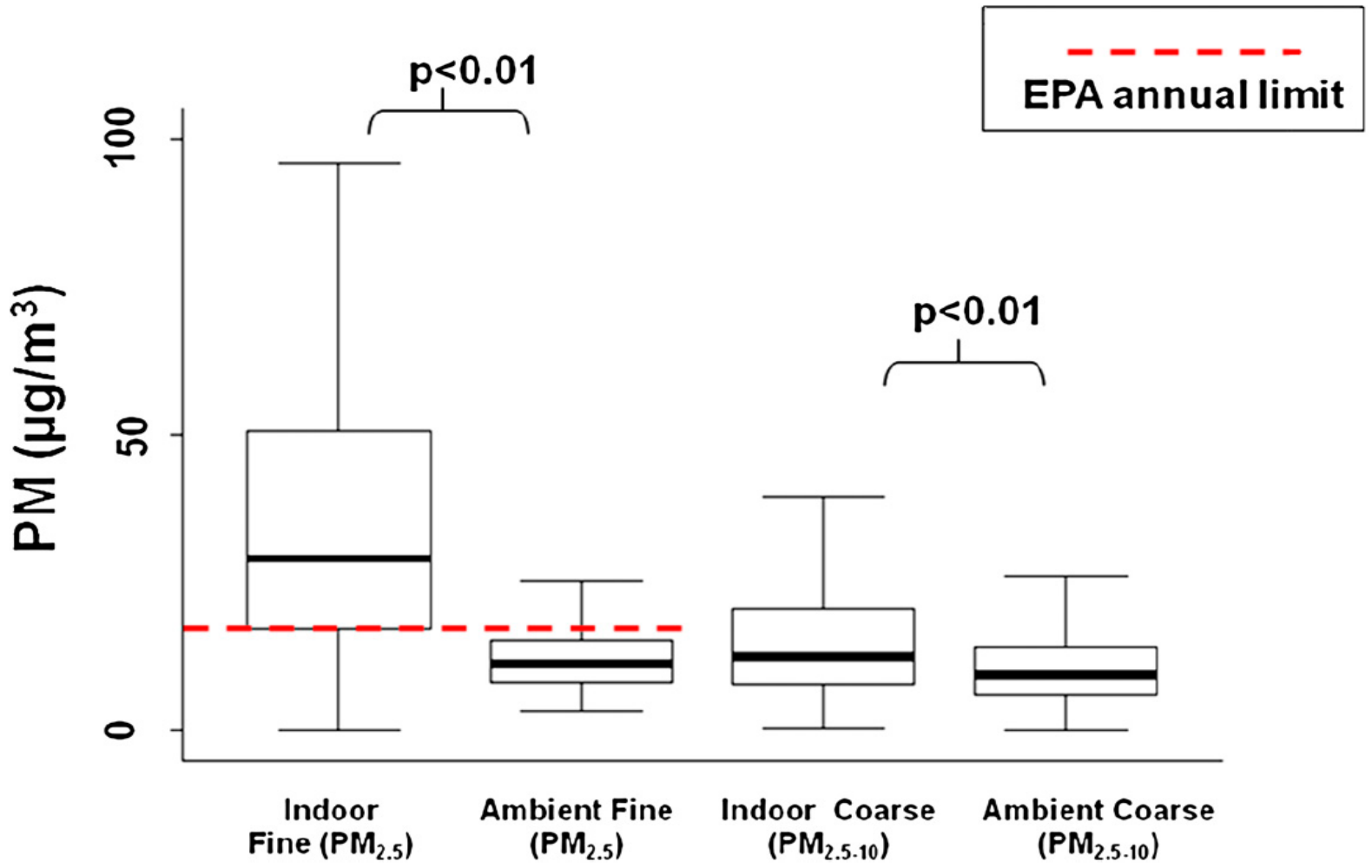




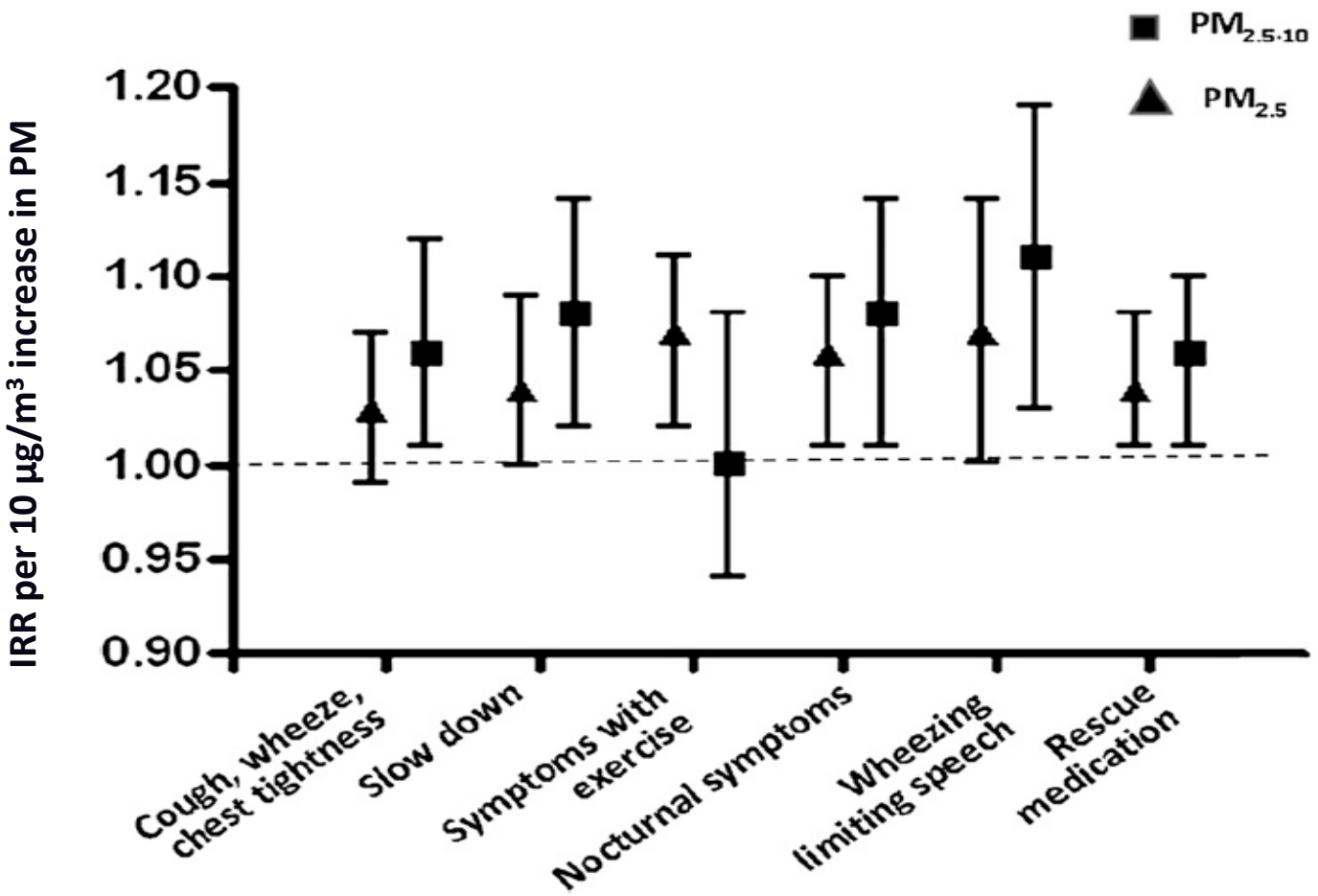


Elevated Indoor PM in Children's Bedrooms



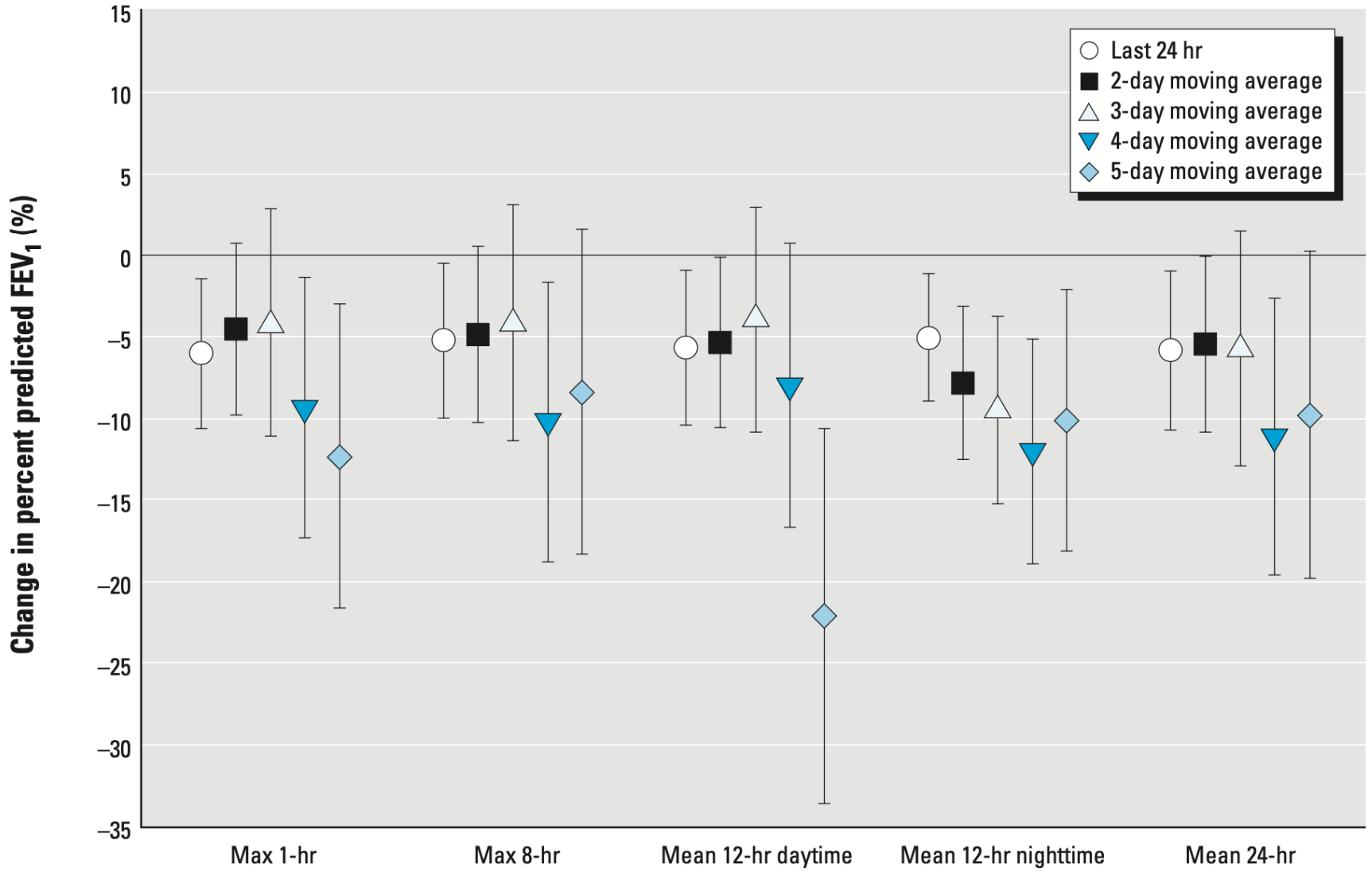
McCormack et al . EHP. 2009

Indoor Particulate Pollution and Asthma Morbidity



*Adjusted for age, gender, race, socioeconomic status, PM or NO_2

McCormack et al. Environ Health Perspectives 2009


Change in percent predicted FEV_1 (%)
15
10
5
0
−5
−10
−15
−20
−25
−30
−35
Last 24 hr
2-day moving average
3-day moving average
4-day moving average
5-day moving average
Max 1-hr
Max 8-hr
Mean 12-hr daytime
Mean 12-hr nighttime
Mean 24-hr

EPA Baltimore City Public Schools (BCPS) Healthy Schools

*EPA Star 83563901
NIH P50ES018176/ EPA RD83615201

School and Student Characteristics

- 84,976 students in pre-k through 12th grade
- 83% African American, 8% White, 7% Hispanic
- 84% low income (based on eligibility for free/reduced-price meals)
- 4.5% English language learners
- 15% with disabilities

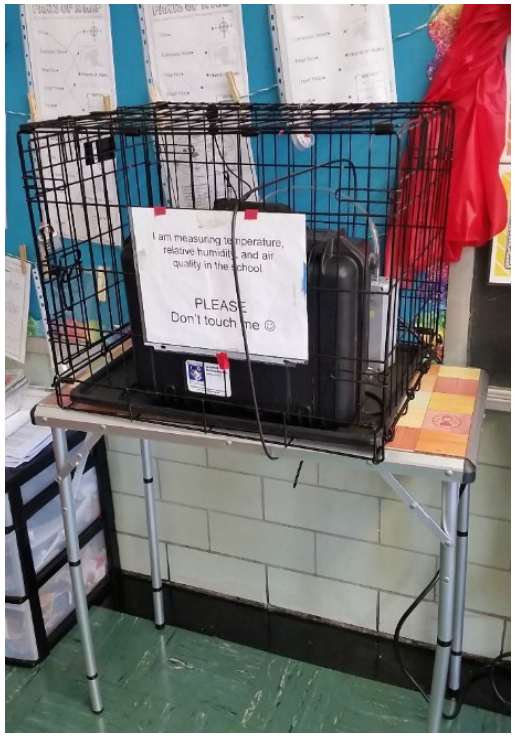
Baltimorecityschools.org
Data from 2014-15

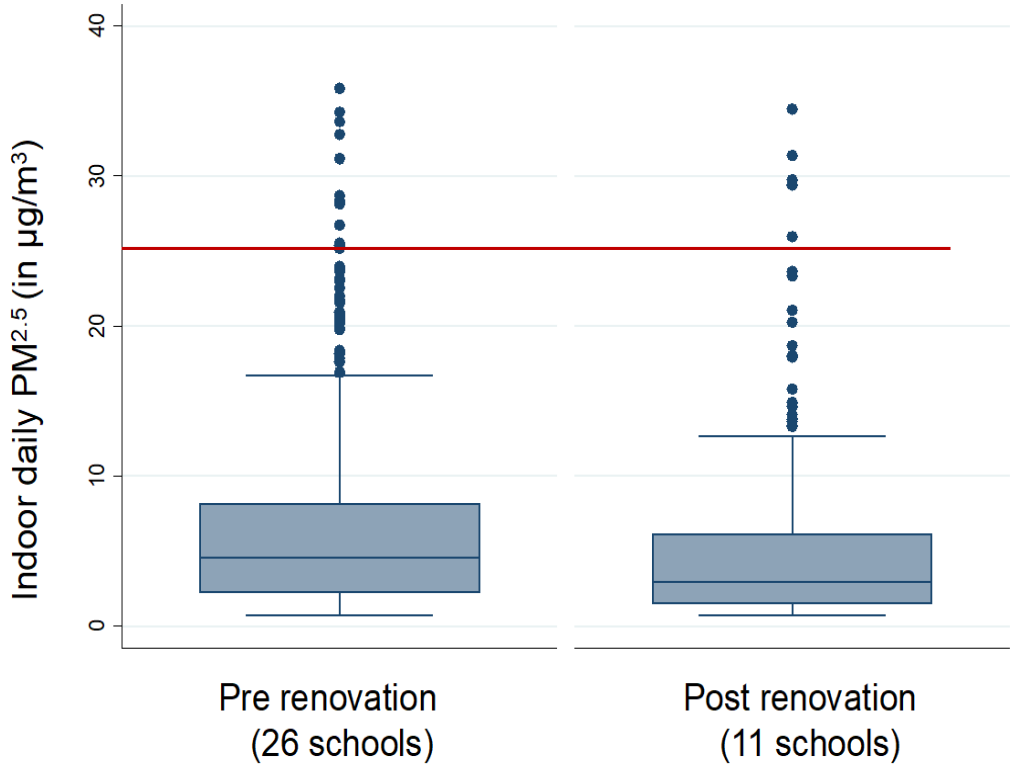
Importance of indoor air quality for children

- Children spend 6-10 hours per day in school
- Impact at a community level
- Few studies have directly assessed school environmental conditions or impact of school renovation

Phipantanakul et al, J Asthma 2011
Fisk, Indoor Air, 2017
Wargoki et al. Indoor Air, 2005

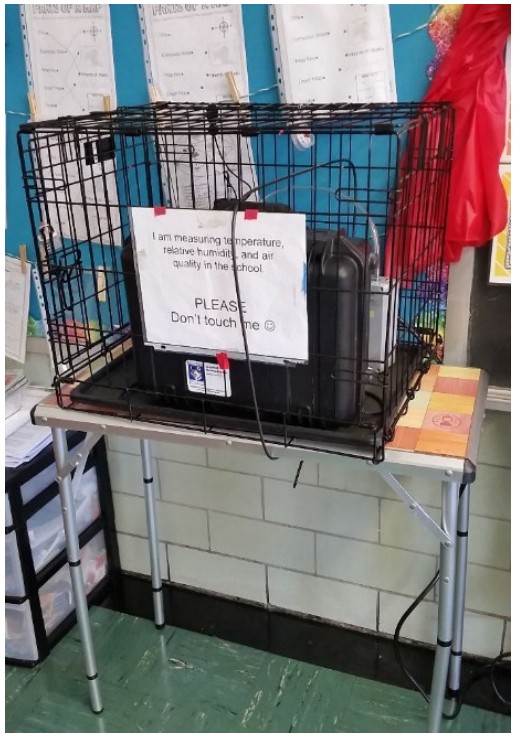
Indoor daily $PM_{2.5}$ in schools before and after renovation





- Dec. 2015- March 2020
- Over 1400 school days monitored
- 4 locations per school in 3 different seasons

Indoor daily $PM_{2.5}$ in schools before and after renovation



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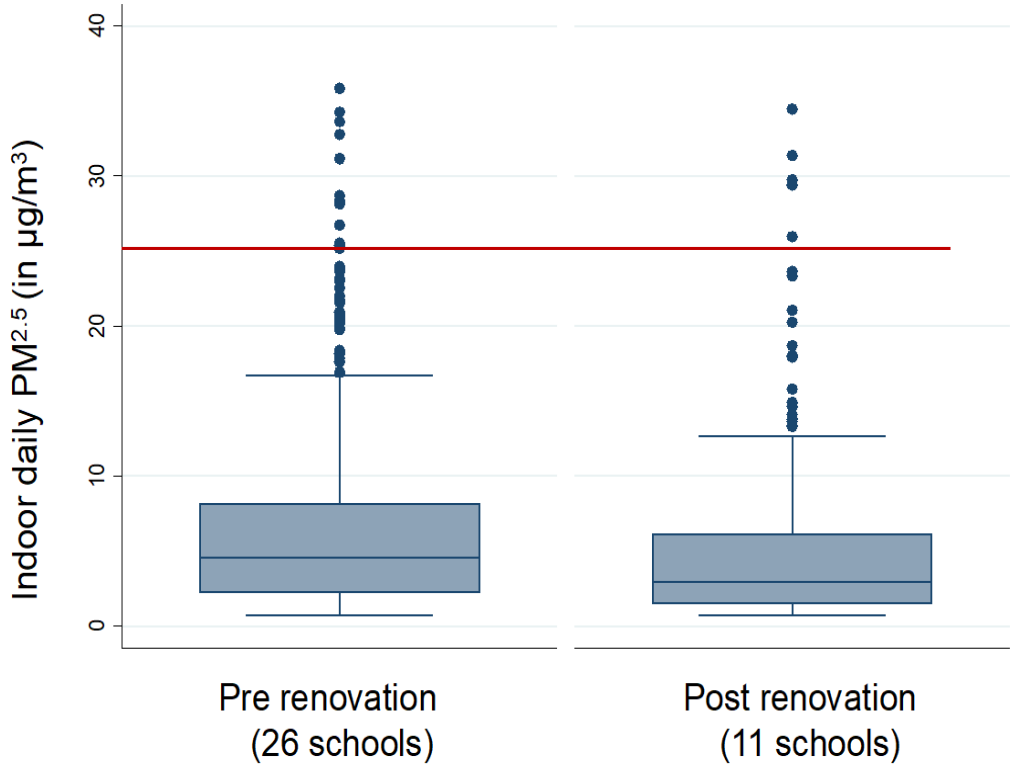


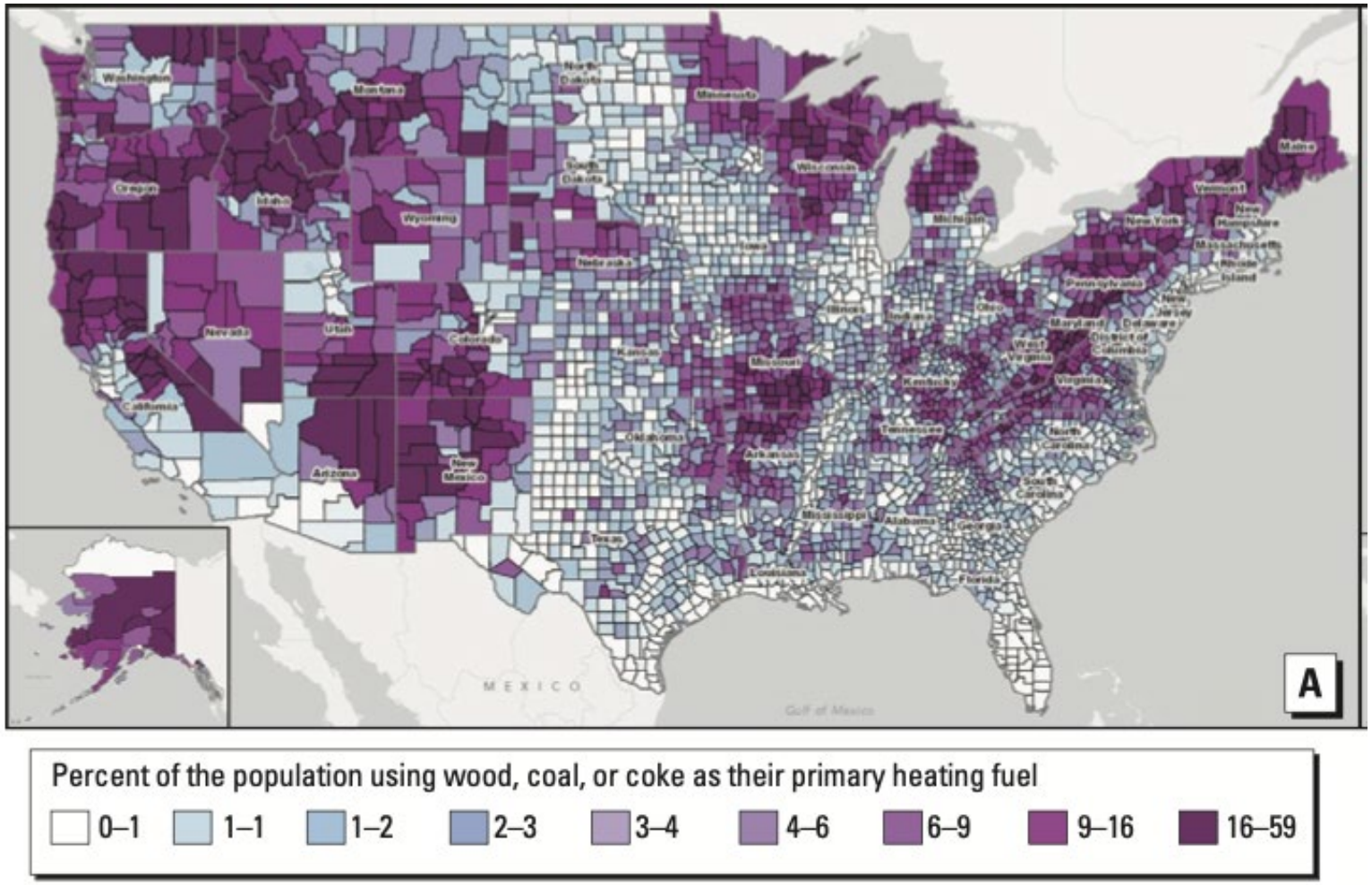
Importance of indoor air quality for children

- Children spend 65-90% of time indoors
- Indoor air pollution contribute to asthma morbidity
- Sources: outdoor air and agents generated by indoor sources
- Most indoor air quality research has been conducted in the home setting

McCormack et al, Environ Health Perspect 2009
Breysse et al, Proc Am Thorac Soc 2010

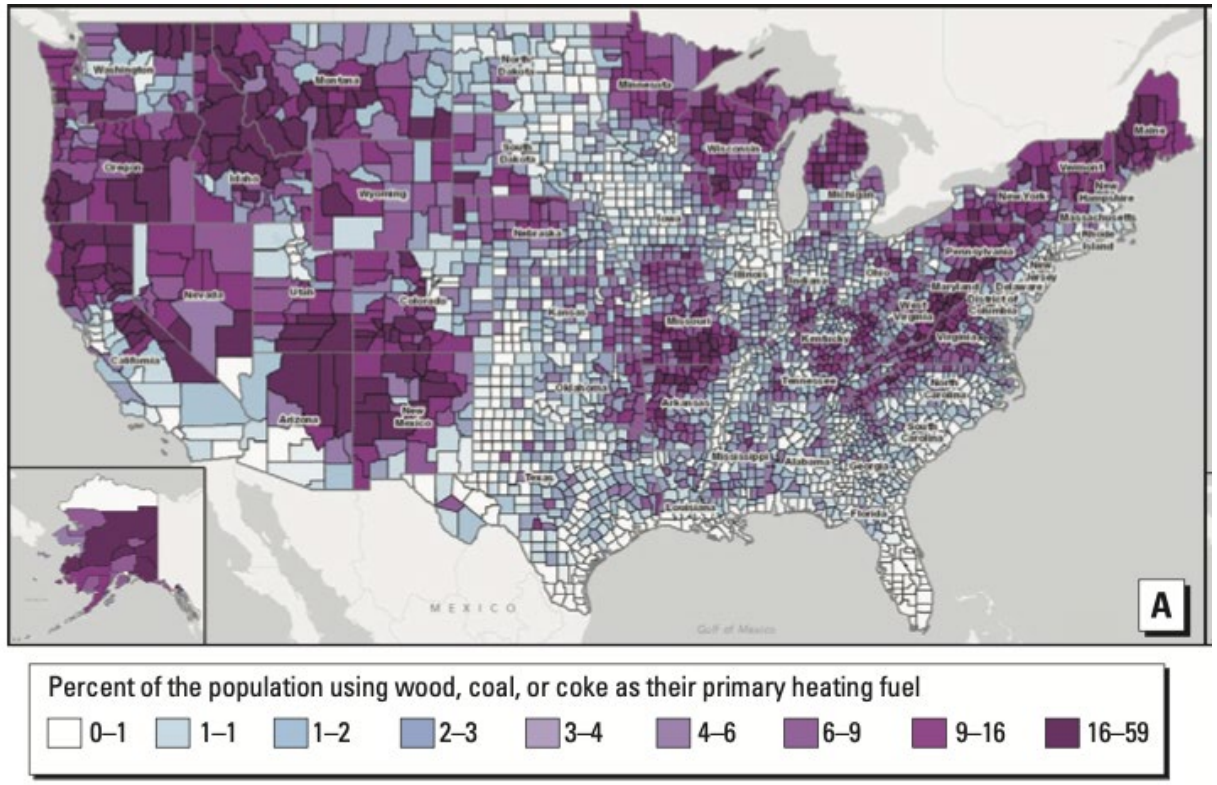
Indoor Air Pollution and COPD

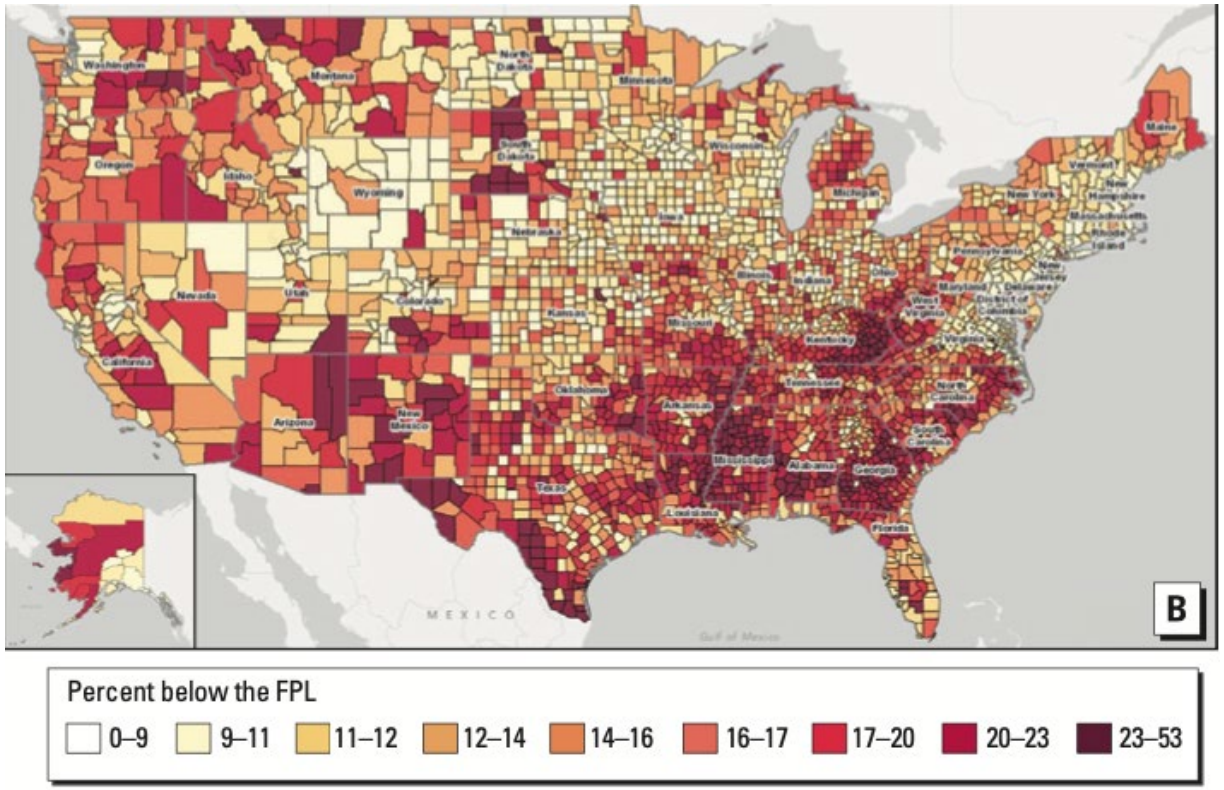
Solid Fuel Use as Primary Heating Source in the United States



Solid fuel is the primary heating source for >2.5 million U.S. households or 6.5 million people.

Rogalsky DK et al. Environmental Health Perspectives 2014 122; 806 810.


A
MEXICO
Percent of the population using wood, coal, or coke as their primary heating fuel
0–1
1–1
1–2
2–3
3–4
4–6
6–9
9–16
16–59


B
MEXICO
Percent below the FPL
0–9
9–11
11–12
12–14
14–16
16–17
17–20
20–23
23–53

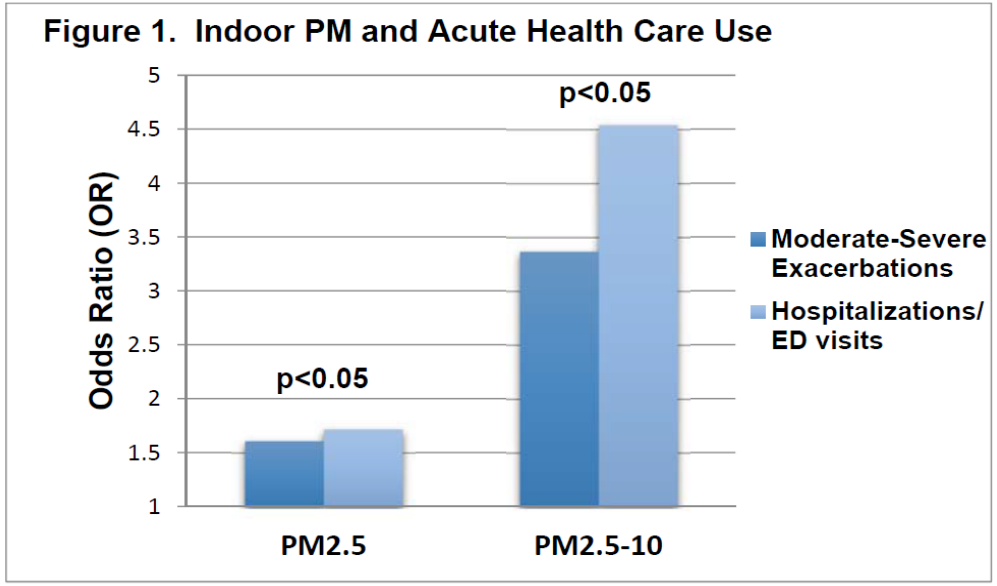
Solids fuel use and respiratory disease

- Heating with solid fuels associated w/ increased COPD prevalence among never smokers (**OR 1.09; P<0.001**)
- Solid fuel use associated w/ COPD among never smokers (**OR 1.12; P<0.001**)
- Indoor cooking with wood and coal associated with increase in asthma prevalence in southeastern Kentucky

Raju et al, Rural Residence and Poverty are Independent Risk Factors for COPD in the United States, AJRCCM 2019
Raju et al, Burden of Rural COPD: Analyses from the National Health and Nutrition Examination Surveys, AJRCCM 2020
Barry et al. Exposure to indoor biomass fuel pollutants and asthma prevalence in Southeastern Kentucky: BOLD study. J Asthma. 2010.

In-Home Air Pollution is linked to Respiratory Morbidity in Former Smokers with Chronic Obstructive Pulmonary Disease

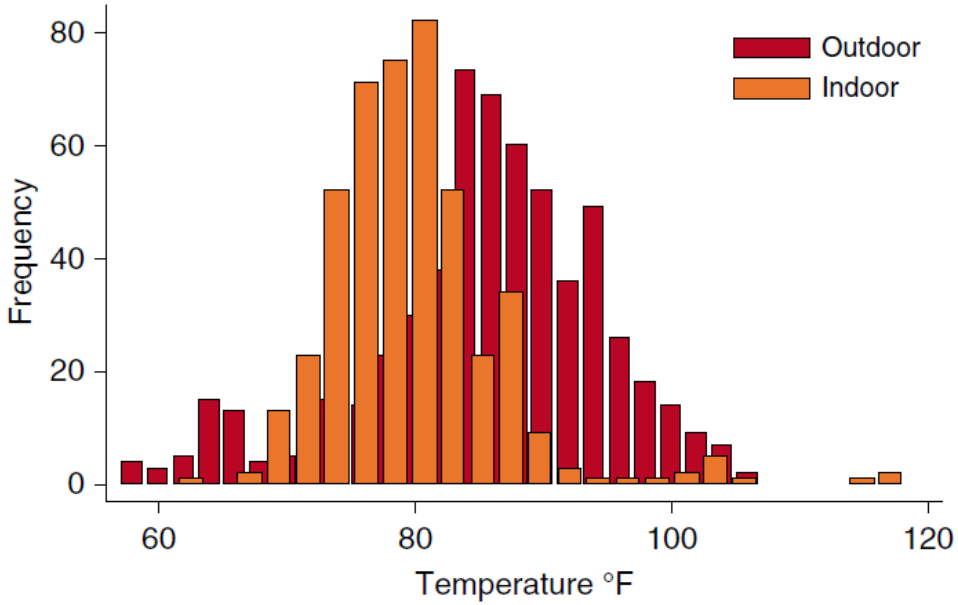
- Indoor PM was relatively low
  - ~11 ug/m^3
- Indoor $PM_{2.5}$ was associated with increases in
  - Severe COPD exacerbations
  - Respiratory Symptoms (MMRC)
  - Respiratory Health Status (SGRQ)
  - Rescue Medication use



Hansel NN et al. In-home air pollution is linked to respiratory morbidity in former smokers with chronic obstructive pulmonary disease. *American journal of respiratory and critical care medicine* 187, no. 10 (2013): 1085-1090.

Synergistic Effect of Indoor Heat and PM Exposure in COPD

- Individuals spent most of their time indoors
- Increases in indoor temperature linked to
  - Increase in respiratory symptoms
  - Increase use of rescue inhalers



McCormack MC et al. Annals of Am Thor Soc 2016

Interactive Effect of Indoor Temperature and Pollution

Estimated effect of 10°F temperature increase with increasing $PM_{2.5}$		
Percentile Indoor $PM_{2.5}$ (ug/m^3)	**Breathlessness Cough Sputum**	**Rescue Inhaler**
25th $PM_{2.5}$ 4.99	**0.36**	**0.25**
50th $PM_{2.5}$ 8.24	**0.54**	**0.42**
75th $PM_{2.5}$ 16.20	**0.98**	**0.85**
95th $PM_{2.5}$ 38.36	**2.21**	**2.02**

McCormack MC et al. Annals of Am Thor Soc 2016

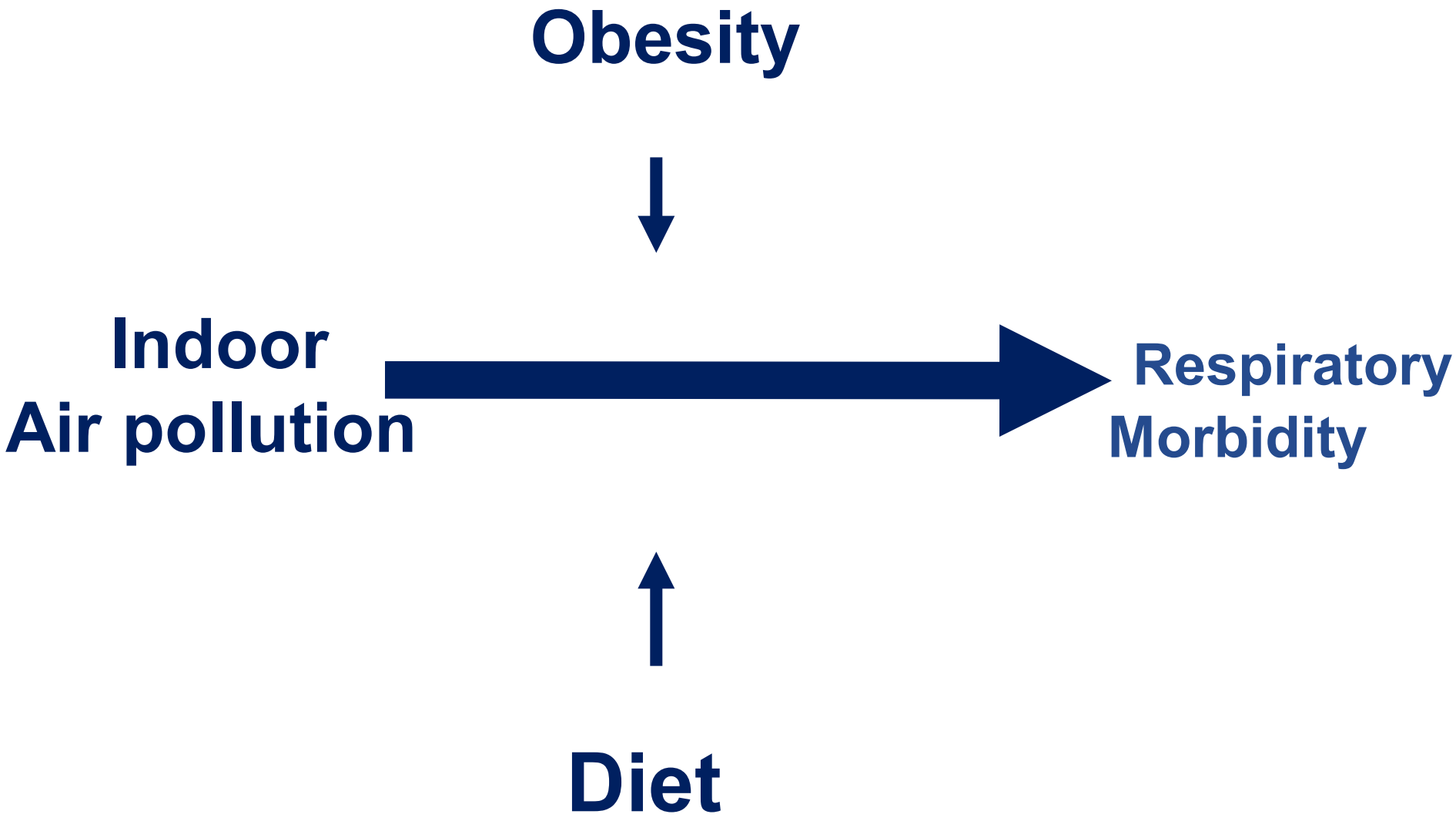
Indoor $PM_{2.5}$ associated with respiratory outcomes among individuals with COPD in a rural community

	β	95% CI		*P*-Value
CAT	0.37	-0.17	0.92	0.182
mMRC	**0.22**	**0.08**	**0.36**	**<0.001**
SGRQ Overall	**1.91**	**0.87**	**2.94**	**<0.001**
Clinical COPD Q (CCQ)	**0.11**	**0.03**	**0.19**	**0.006**
Rhinitis (RCAT)	**-0.56**	**-1.11**	**-0.01**	**0.046**
FEV1 % Predicted	-0.04	-1.30	1.23	0.954

*Beta represents the predicted change in the level of outcome for every doubling of $PM_{2.5}$.

**Models adjusted for age, gender, education, obesity, pack-years, and season.

Susceptibility Factors


Obesity
Indoor
Air pollution
Respiratory
Morbidity
Diet

Being overweight increases susceptibility to indoor pollutants among urban children with asthma

Kim D. Lu, MD,[a] Patrick N. Breysse, PhD,[b] Gregory B. Diette, MD, MHS,[c] Jean Curtin-Brosnan, MA,[a] Charles Aloe, MPH,[a] D'Ann L. Williams, DrPH,[b] Roger D. Peng, PhD,[d] Meredith C. McCormack, MD, MHS,[c] and Elizabeth C. Matsui, MD, MHS[a] *Baltimore, Md*

- 150 children with persistent asthma, age 5-17.
- BMI
  - Underweight (<5th percentile) 4%
  - Normal weight (5-<85th %ile) 52%
  - Overweight (85th-<95th %ile) 16%
  - Obese (>95th %ile) 28%
- Overweight/obese had increased nocturnal symptoms and exercise-related symptoms

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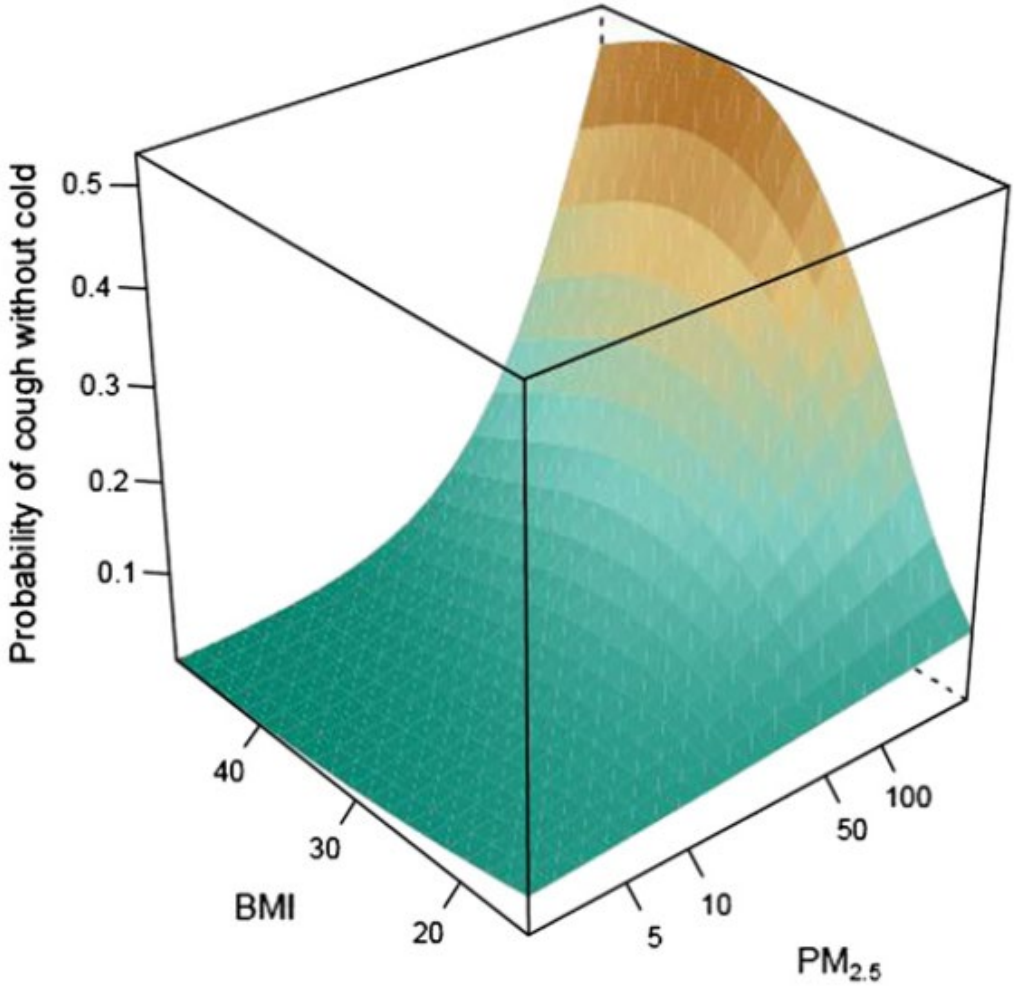
Table 1. Indoor $PM_{2.5}$ and asthma symptoms by BMI category*

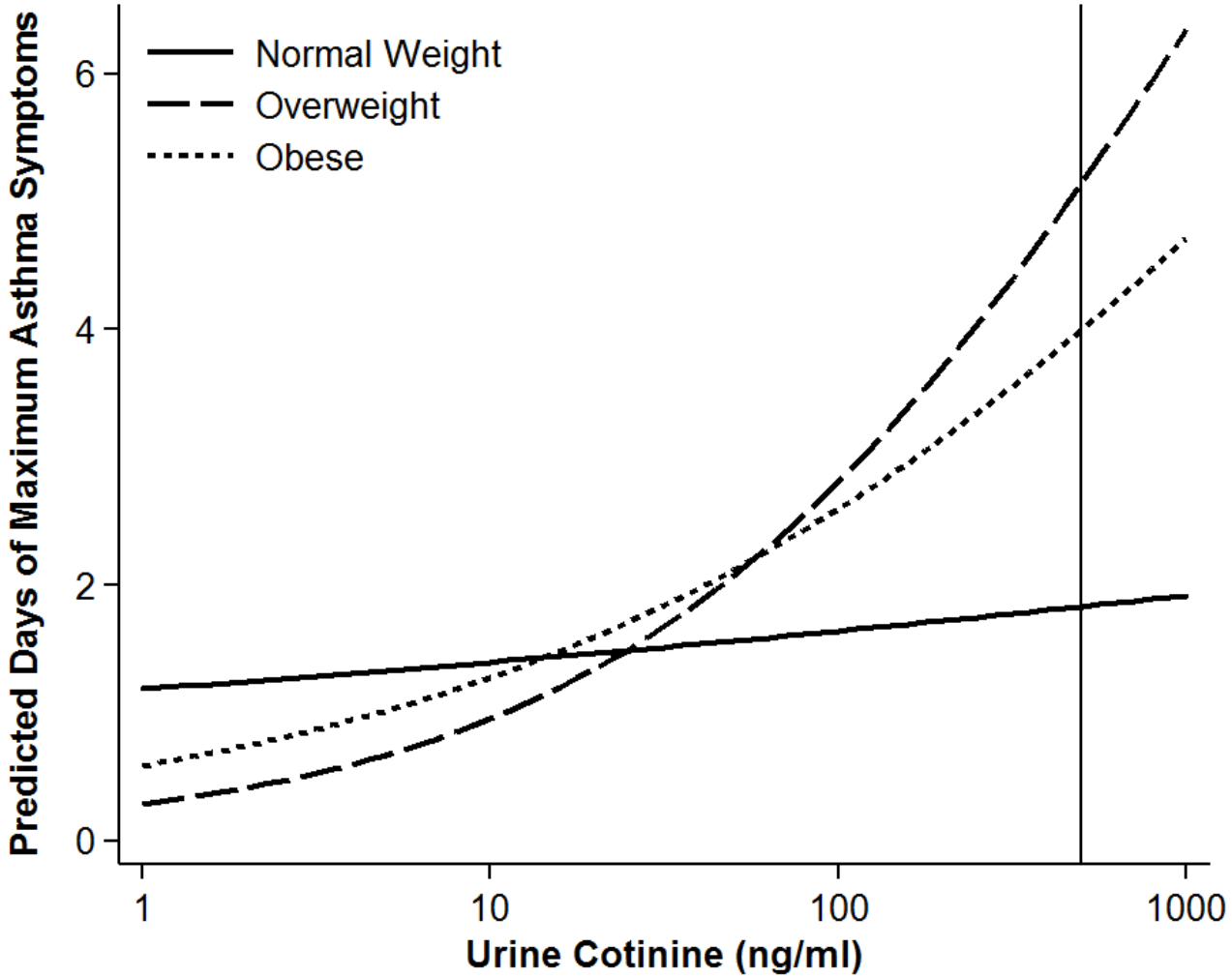
Outcome	Normal Weight	Overweight	Obese	P-value interaction
Cough, wheeze, chest tightness	**2.19 (1.18-4.08)**	**2.84 (1.16-6.95)**	2.23 (0.99-5.05)	0.05
Nocturnal	1.04 (0.52-2.07)	**5.59 (1.57-19.94)**	3.02 (0.88-10.39)	0.24
Exercise	1.70 (0.74-3.93)	**4.36 (1.14-16.71)**	3.06 (0.87-10.73)	0.16
Cough without cold	2.06 (0.79-5.37)	**3.17 (1.33-7.57)**	**5.00 (1.37-18.22)**	0.02
Slowed activity	1.58 (0.79-2.99)	**2.88 (1.15-7.23)**	2.45 (0.78-7.65)	0.08
SABA use	**1.97 (1.01-3.84)**	**3.31 (1.37-8.03)**	2.26 (0.84-6.03)	0.57

*** (n=141 inner-city children)**

The Interactive Effect of Body Mass and $PM_{2.5}$ on Asthma Symptoms

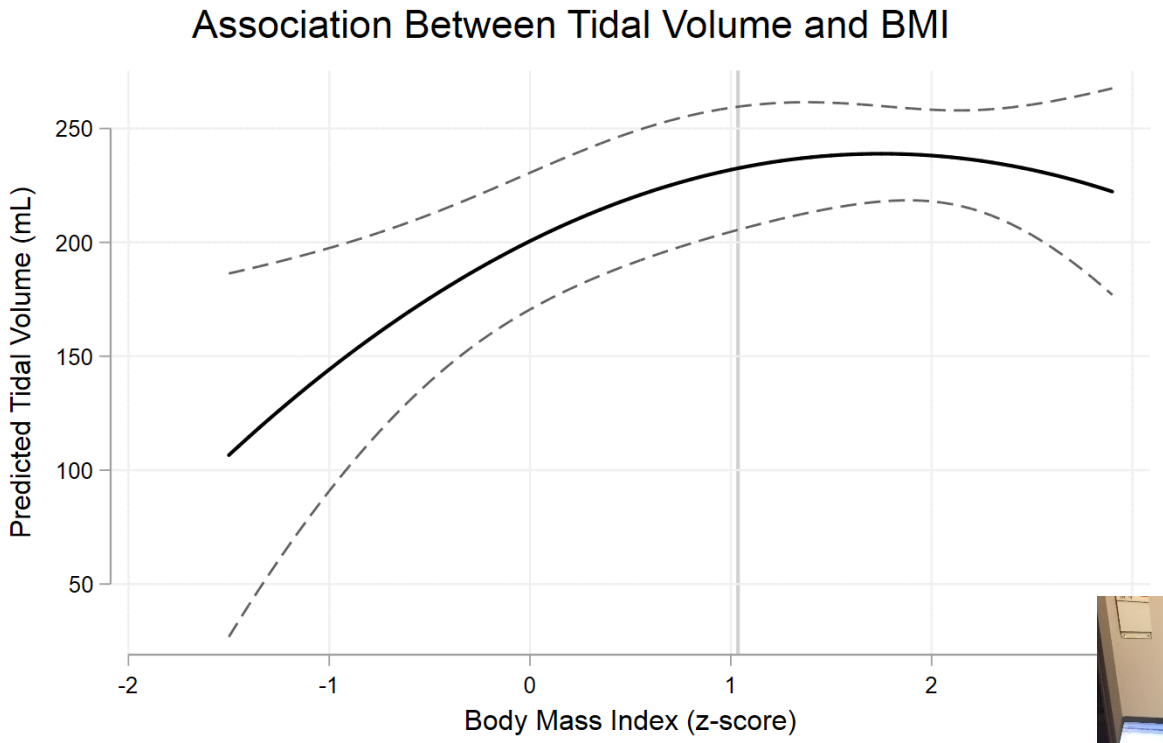


Interactive Effect of Body Mass and Urine Cotinine on Asthma Symptom Days



Wu TD, Brigham EP, Peng R, Koehler K, Rand C, Matsui EC, Diette GB, Hansel NN, **McCormack MC**. Overweight/obesity enhances associations between secondhand smoke exposure and asthma morbidity in children. J Allergy Clin Immunol Pract. 2018 May 3.

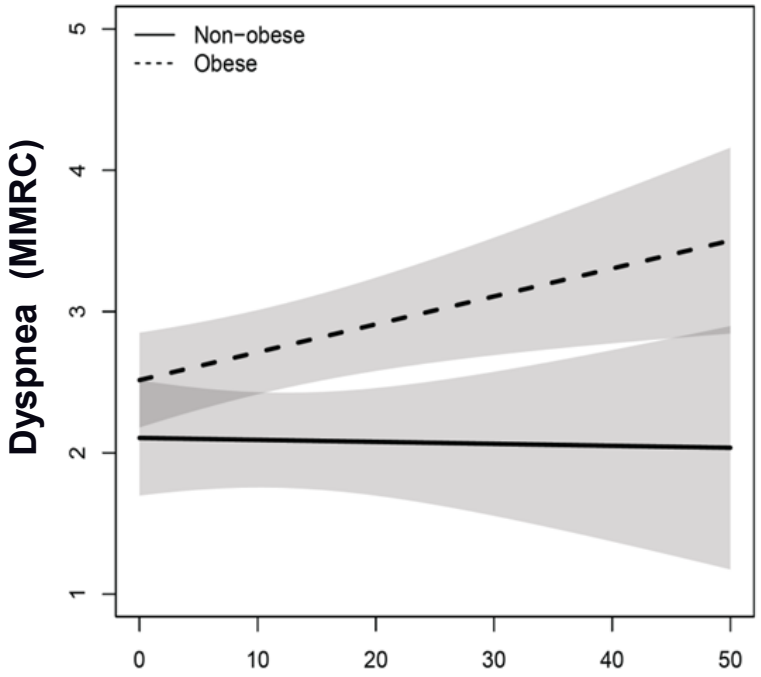
AIRWEIGHS: BMI association with tidal volume

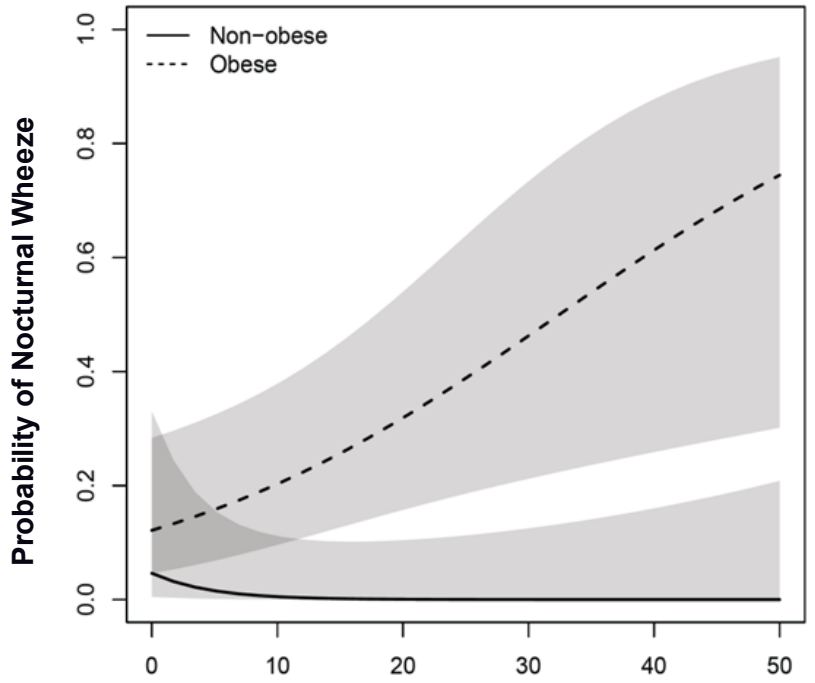


Mean difference between normal weight and overweight/obese: 46.5 mL (95% CI 3 to 90 mL, p=0.04)

*Adjusted for age, sex, race, and height

Susceptibility to PM in COPD: Obesity

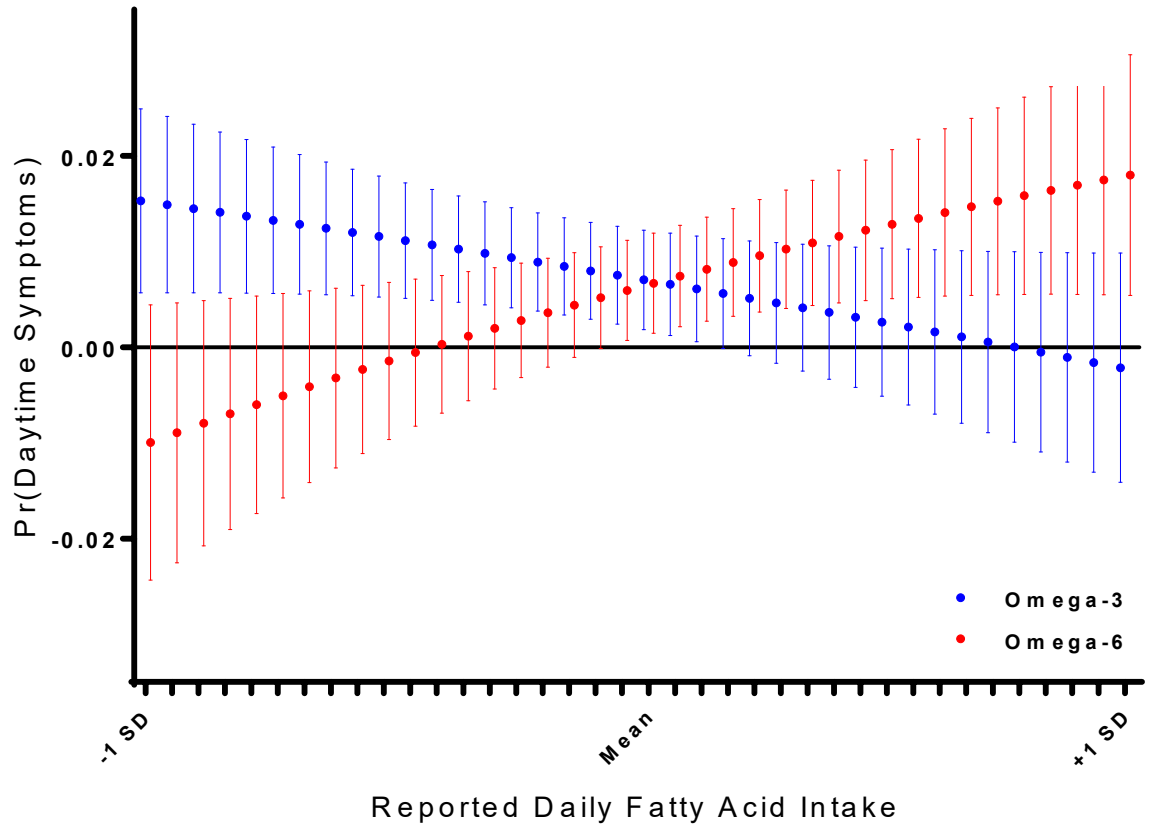




- Systemic inflammatory response exaggerated among obese versus non-obese with exaggerated increases in neutrophils, eosinophils, IL-6, CRP, fibrinogen

McCormack et al. Obesity as a Susceptibility Factor to Indoor Particulate Matter Health Effects in COPD.Eur Respir J. 2015 Jan 8.

The Effect of Indoor $PM_{2.5}$ on Daytime Symptoms Varies with Omega-3 and Omega-6 Fatty Acid Intake



Asthma Diet Children's Cohort Study N=147

Brigham EB et al. Omega-3 and Omega-6 Intake Modifies Asthma Severity and Response to Indoor Air Pollution in Children. AJRCCM 2019.

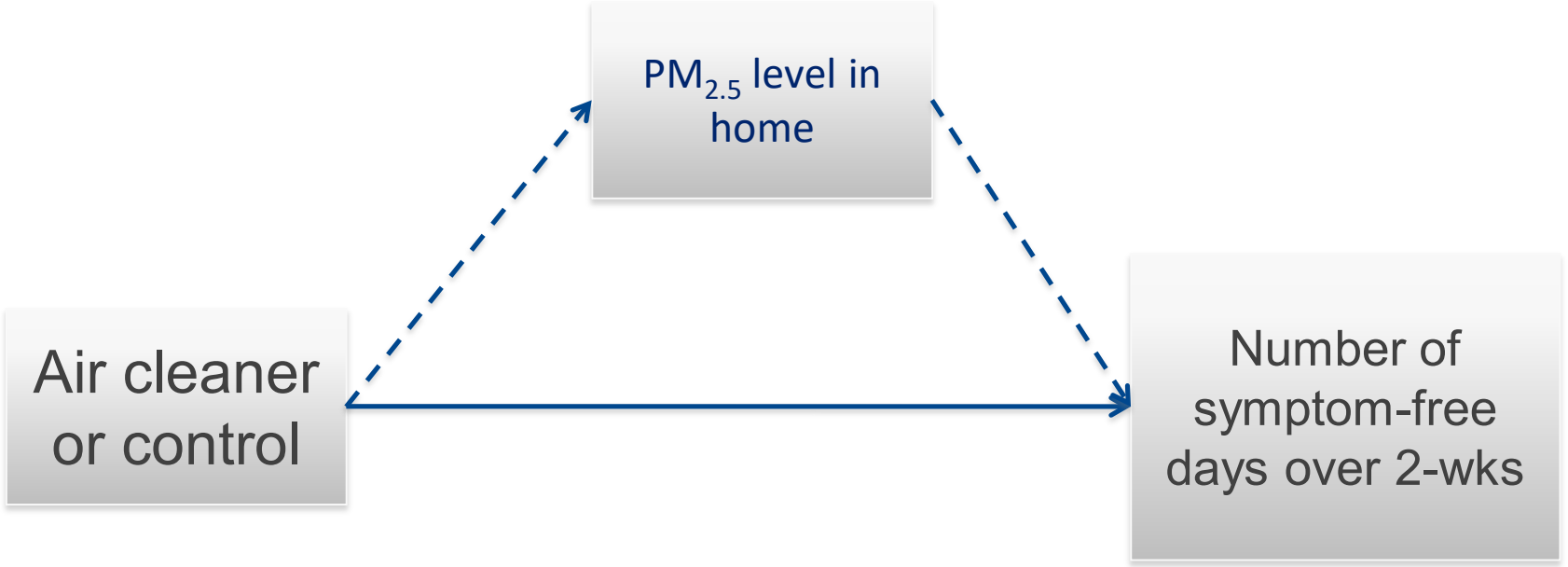
Environmental Interventions to Improve Health Outcomes

PREACH Study

- RCT in East Baltimore to lower indoor $PM_{2.5}$ levels
- Three groups (~40 in each group):
  - Control
  - Air Purifier with HEPA filter
  - Air Purifier + Health Coach
- 126 children 6-12 yrs old with asthma
- Homes had to have a smoker (> 5 cigs/day)
- Baseline + 6-month clinic and home visit
- Outcome: Symptom-free days

Butz, AM et al. (2011). A randomized trial of air cleaners and a health coach to improve indoor air quality for inner-city children with asthma and secondhand smoke exposure. *Archives of pediatrics & adolescent medicine*, *165*(8), 741-748.

PREACH Study Design



Butz, AM et al. (2011). A randomized trial of air cleaners and a health coach to improve indoor air quality for inner-city children with asthma and secondhand smoke exposure. *Archives of pediatrics & adolescent medicine*, *165*(8), 741-748.

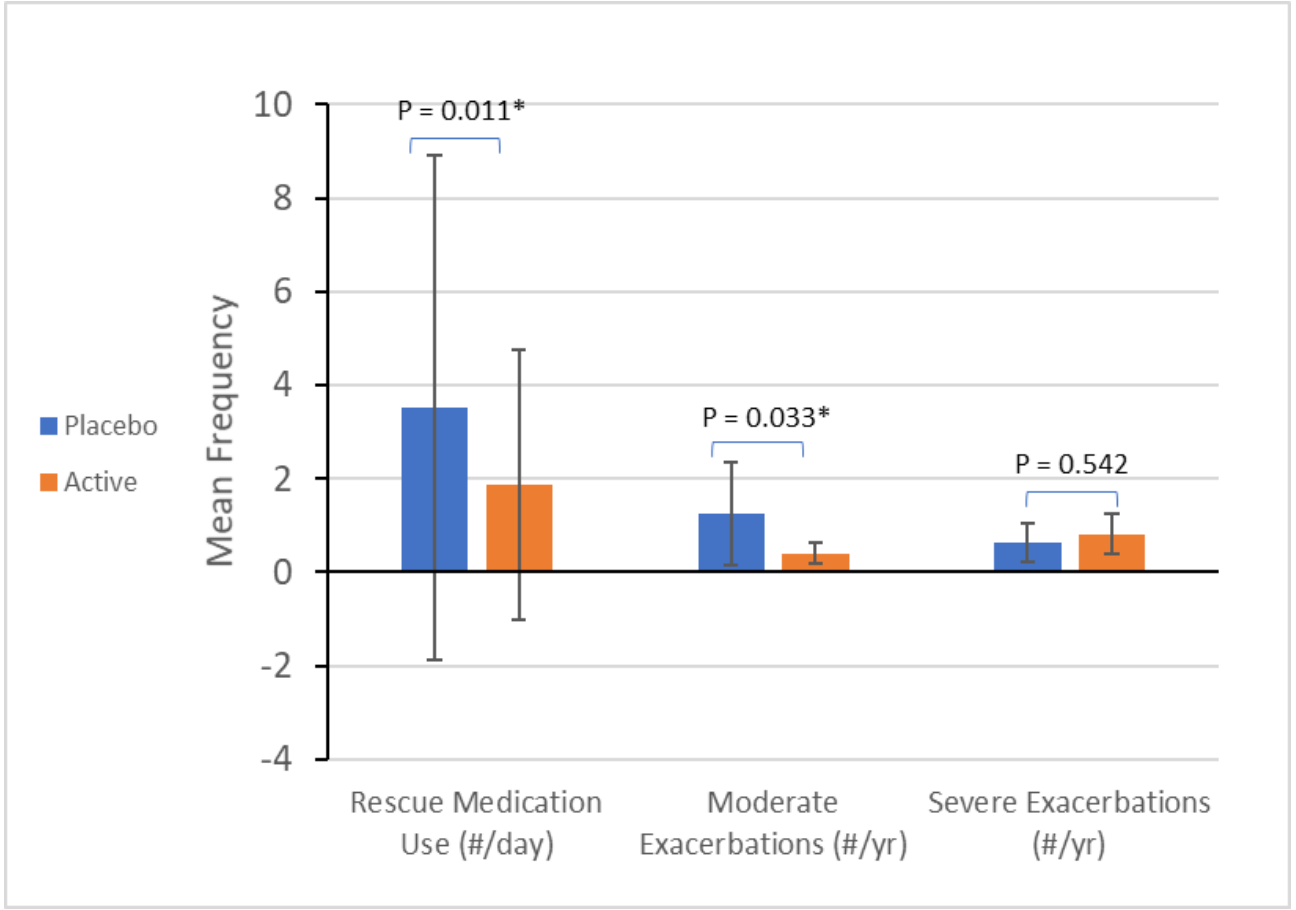
Health Effects in PREACH

- $PM_{2.5}$ reduced by ~50%
- 14-18% increase in symptom-free days among those that received an air cleaner versus control
- Equivalent to 33 additional symptom-free day per year
- Similar effect size demonstrated in large RCT for leukotriene modifiers[1]

Butz, AM et al. (2011). A randomized trial of air cleaners and a health coach to improve indoor air quality for inner-city children with asthma and secondhand smoke exposure. *Archives of pediatrics & adolescent medicine*, *165*(8), 741-748.

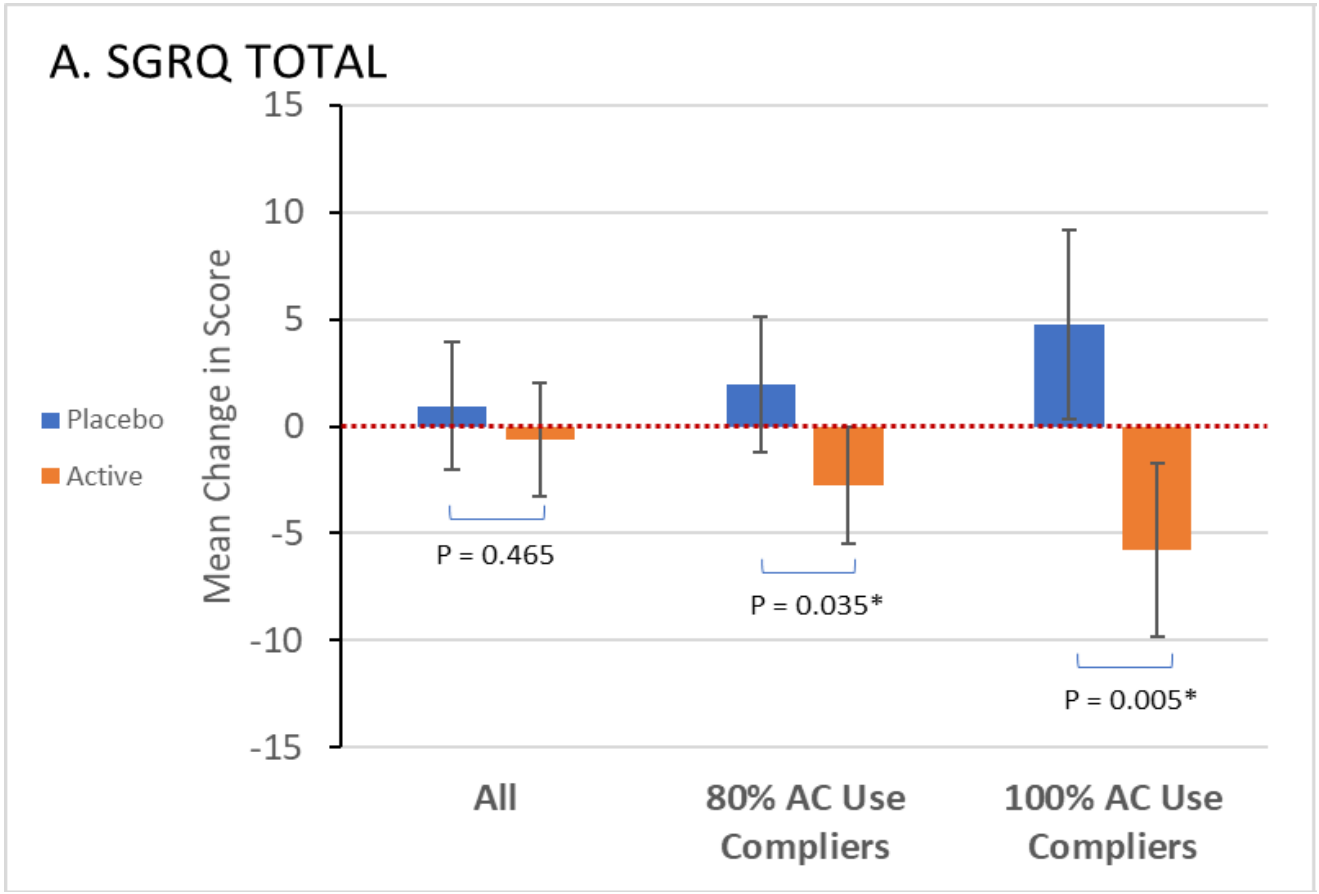
Clean Air Trial

- 116 former smokers with COPD
- Randomized to 2 HEPA air cleaners versus placebo
- 6 month follow-up



Hansel NN et al. Randomized Clinical Trial of Air Cleaners to Improve Indoor Air Quality and COPD Health: Results of the CLEAN AIR STUDY. Manuscript under review.

Clean Air Trial



- Adherence to environmental interventions is a key aspect of implementation

Hansel NN et al. Randomized Clinical Trial of Air Cleaners to Improve Indoor Air Quality and COPD Health: Results of the CLEAN AIR STUDY. Manuscript under review.

Performance outcomes

1. Attendance rate (Number of students in attendance / Total number registered)
   - Pre-renovation mean: .901 (SD: 0.063)

2. Chronic absence rate (Number of students who miss > 20 days if enrolled for 90+ Days)
   - Pre-renovation mean: .275 (SD: 0.167)

3. PARCC mean score math (score range: 650-850)
   - Pre-renovation mean: 706.9 (SD: 12.4)

4. PARCC mean score English (score range: 650-850)
   - Pre-renovation mean: 707.3 (SD: 12.4)

Implications

- Indoor particulate pollution is associated with increased asthma and COPD morbidity
- Obesity and poor diet may increase susceptibility to air pollution health effects
- Improving indoor air quality represents a therapeutic target to modify disease activity

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QUESTIONS AND DISCUSSION

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