The Impact of Air Pollution on Human Health

Fernando Holguin MD MPH
Associate Professor of medicine and Pediatrics
Director, Clinical and Translational Research Center , MUH
University of Pittsburgh Medical Center

Air pollution, a complex mixture of particles and gases

Criteria air pollutants

Ground-level ozone	→	Forms from the reaction of pollutants emitted by industrial facilities and motor vehicles
Particulate matter (PM)	→	Diverse chemical and physical substances that exist in discrete particles over a wide range of particles. Derived from anthropogenic sources (<2.5 microns); whereas PM10 mostly derive from dust dispersion
Lead	→	Used to be a major air pollution component until banned in gasoline; more of an industrial pollutant

Air pollution, a complex mixture of particles and gases

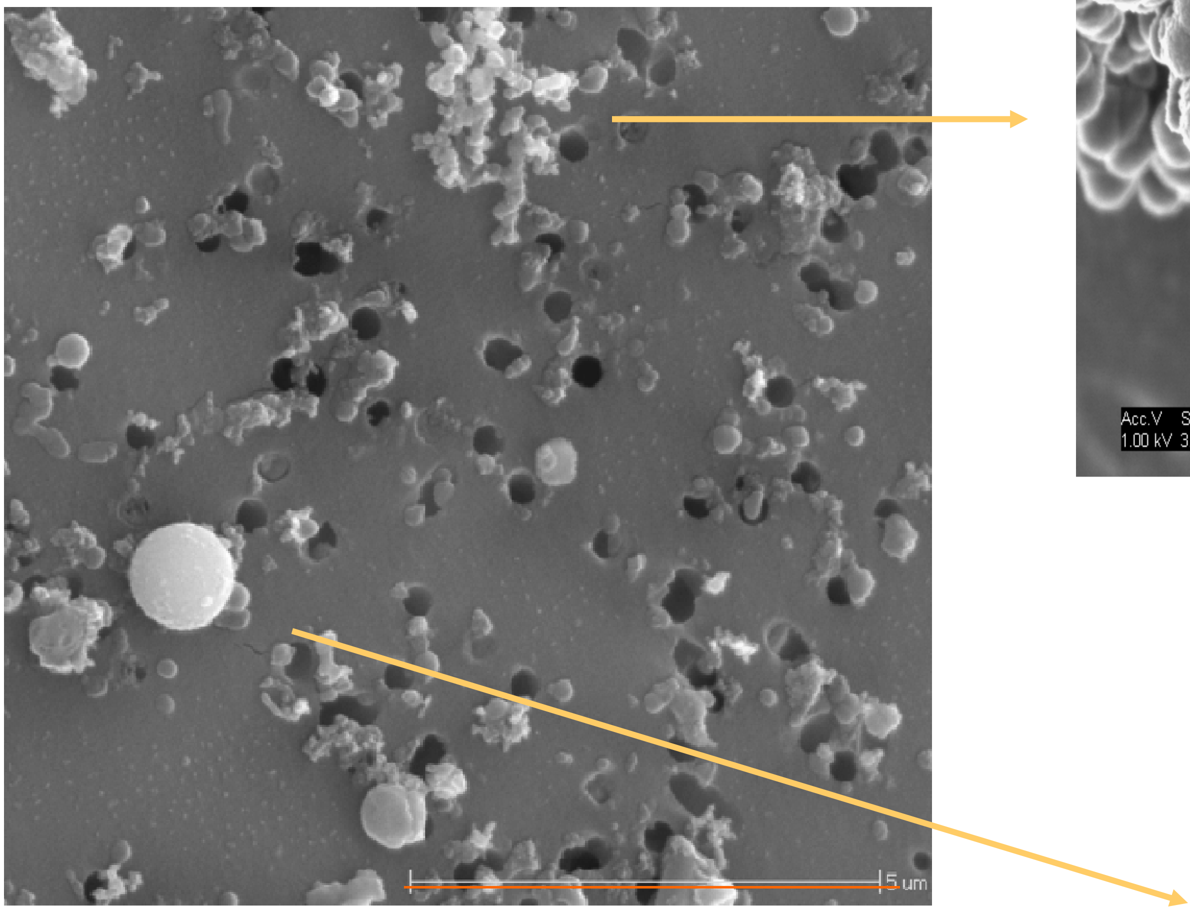
Criteria air pollutants

Sulfur – dioxide	→	Gas emitted primarily by fuel combustion from electrical utilities and industry
Carbon dioxide	→	Gasoline-fueled vehicles and on-road mobile sources
Nitrogen dioxide	→	Gas emitted by trucks, cars, buses, power plants, non-road engines and equipment

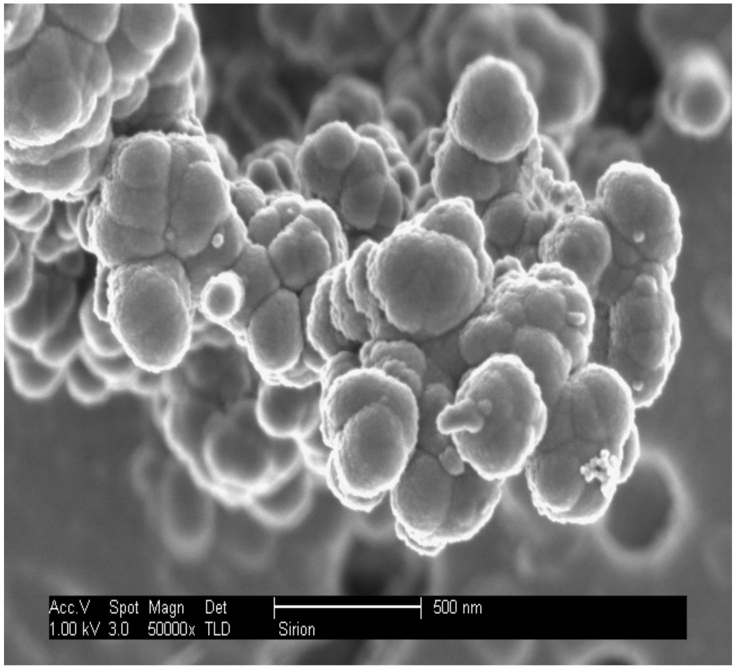
Source : Environmental Protection Agency


TYPEWRITERS
OFFICE MACHINES

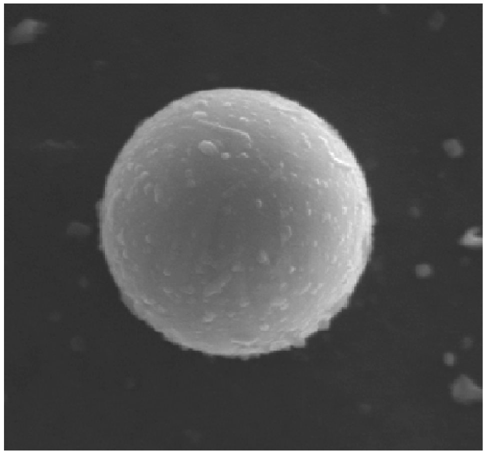
PM < 2.5 Ambient Sample – Field Image

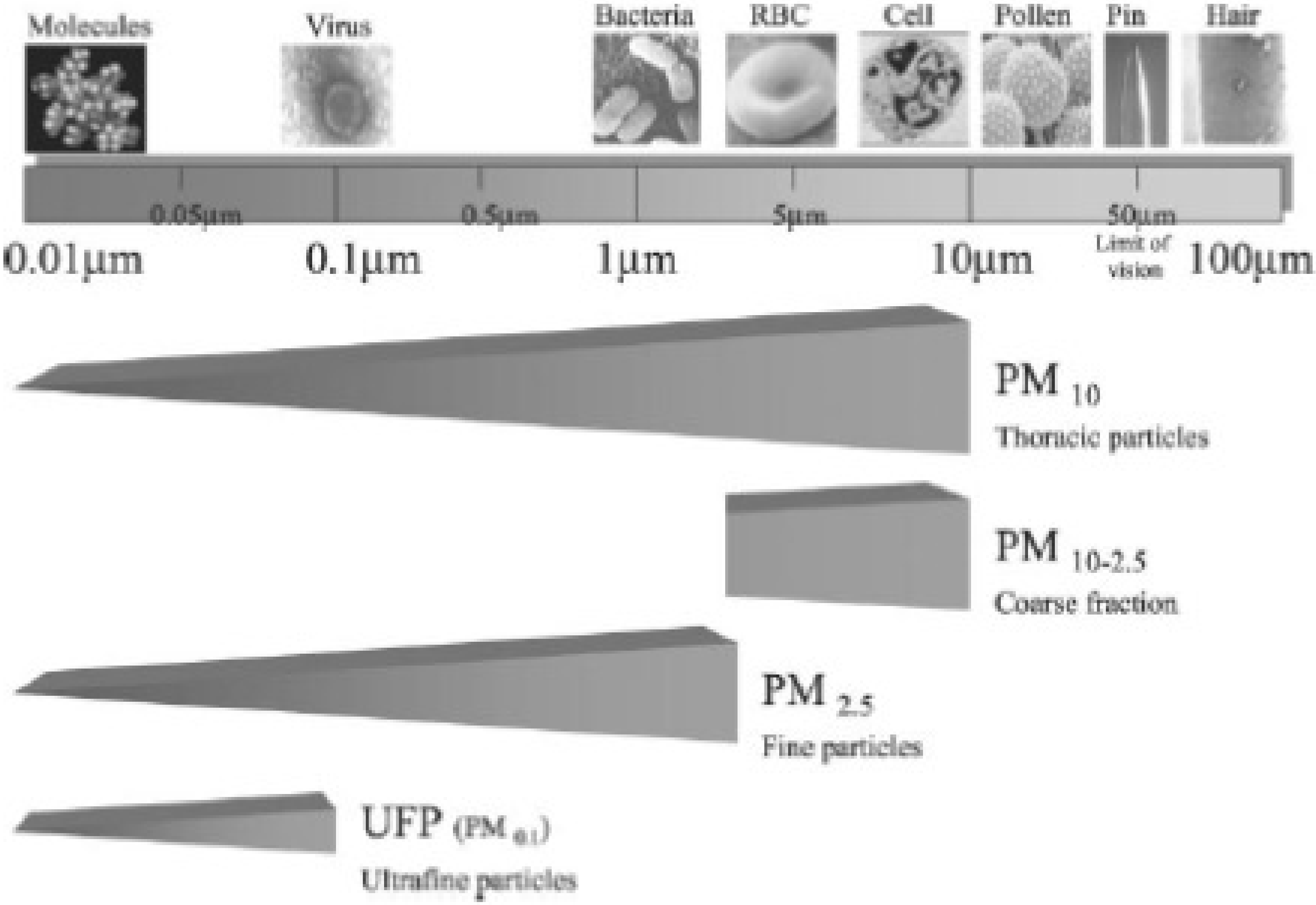


Mexico City sample from
The Desert Research Institute, Reno Nevada

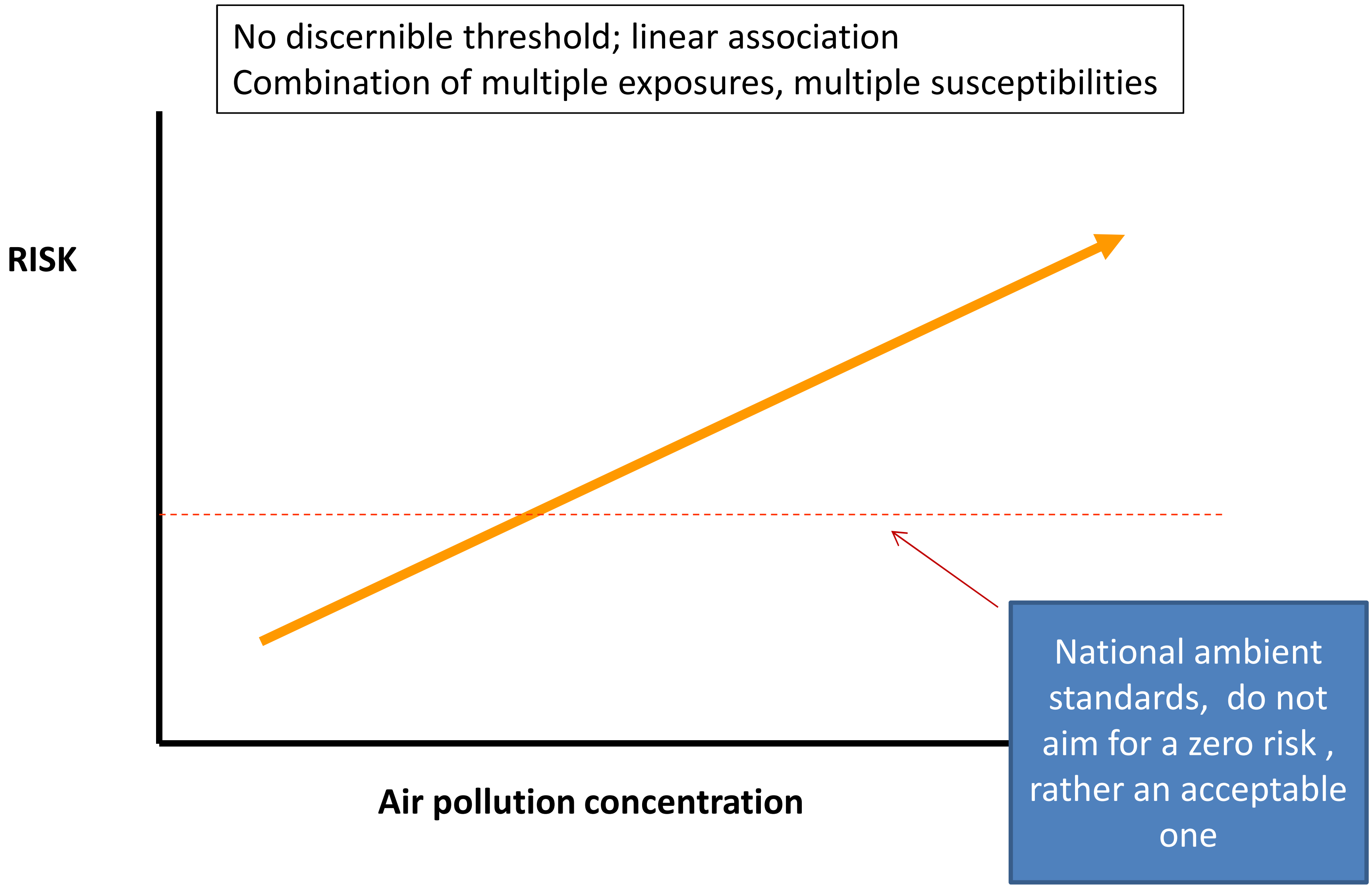


Fossil Fuel Combustion




Molecules
Virus
Bacteria
RBC
Cell
Pollen
Pin
Hair
0.05μm
0.5μm
5μm
50μm
0.01μm
0.1μm
1μm
10μm
Limit of vision
100μm
PM 10
Thoracic particles
PM 10-2.5
Coarse fraction
PM 2.5
Fine particles
UFP (PM 0.1)
Ultrafine particles

Air pollution levels and health risks

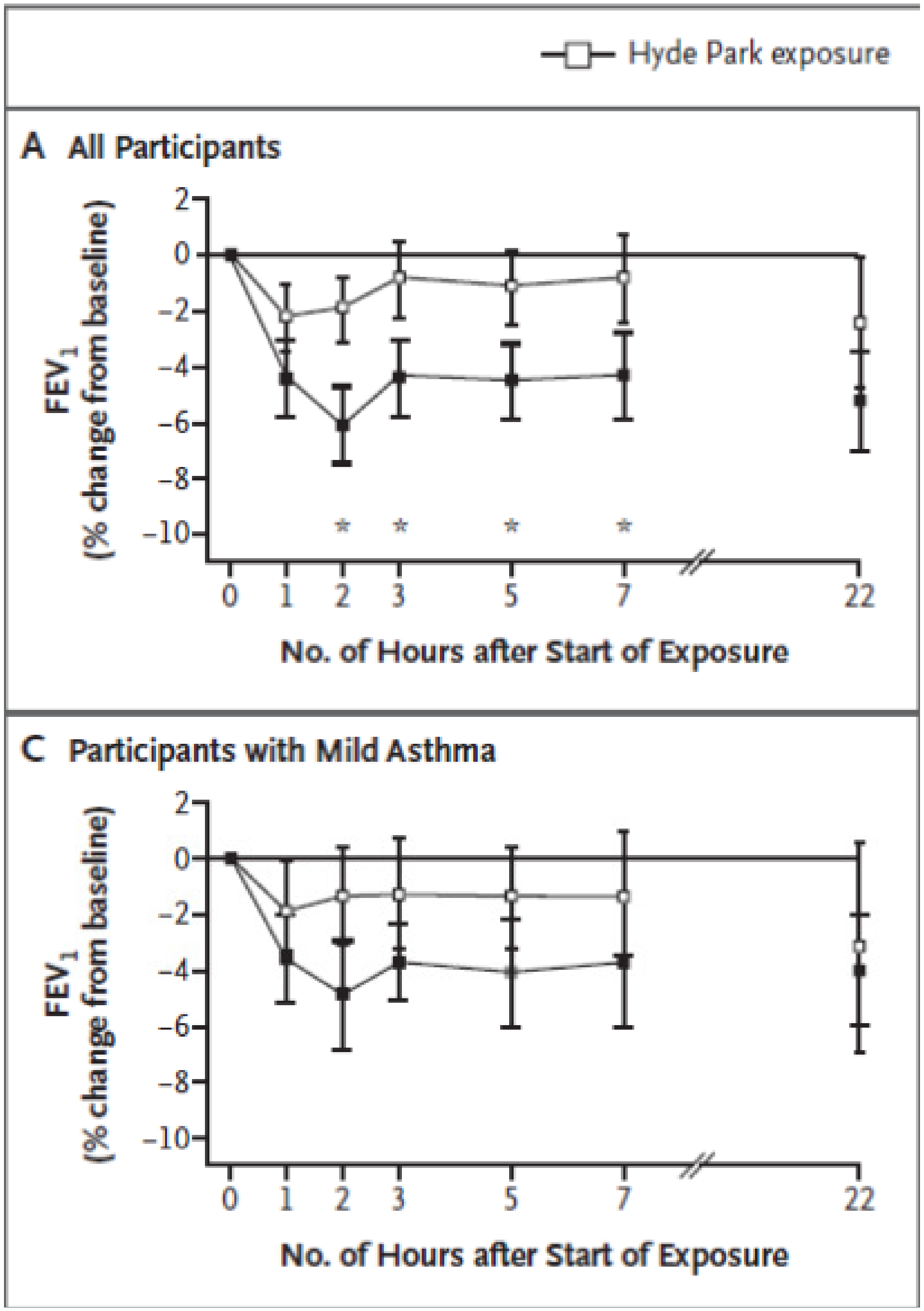


Relatively short-term exposures translate into adverse
Airway functional and inflammatory responses

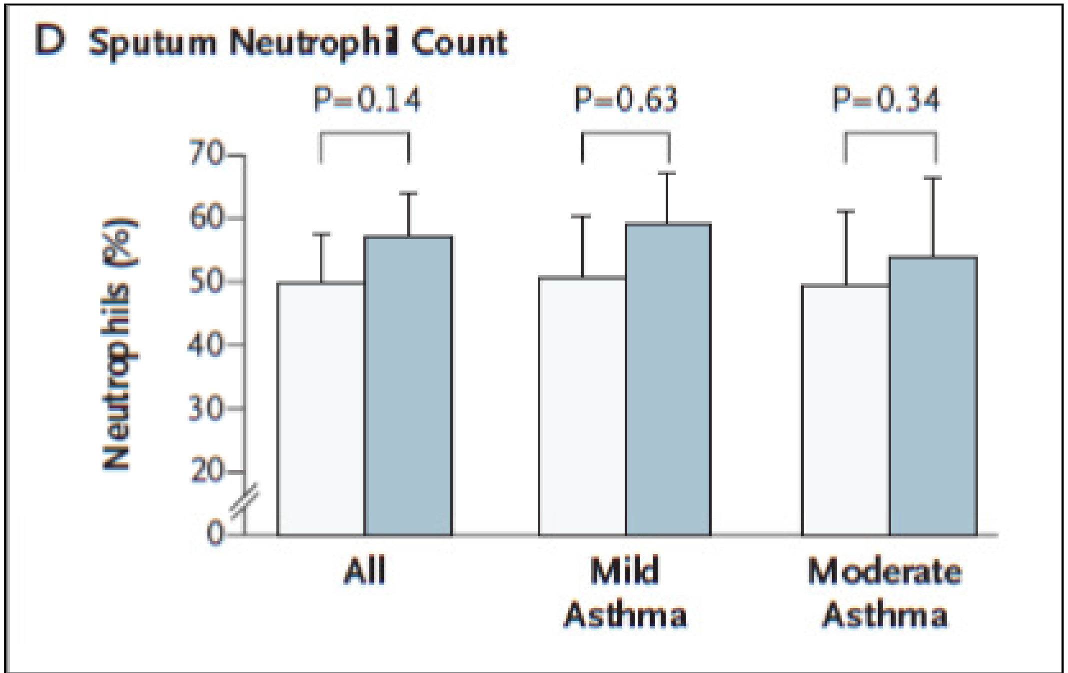
Oxford Street

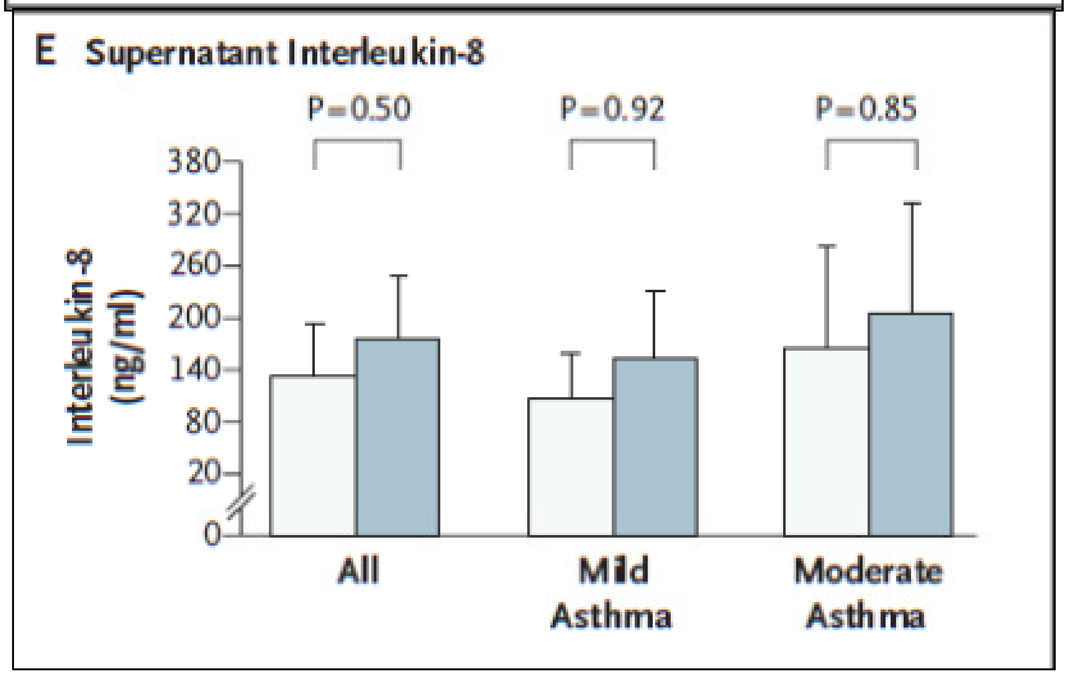
Hyde Park

McCreanor et al NEJM 2007



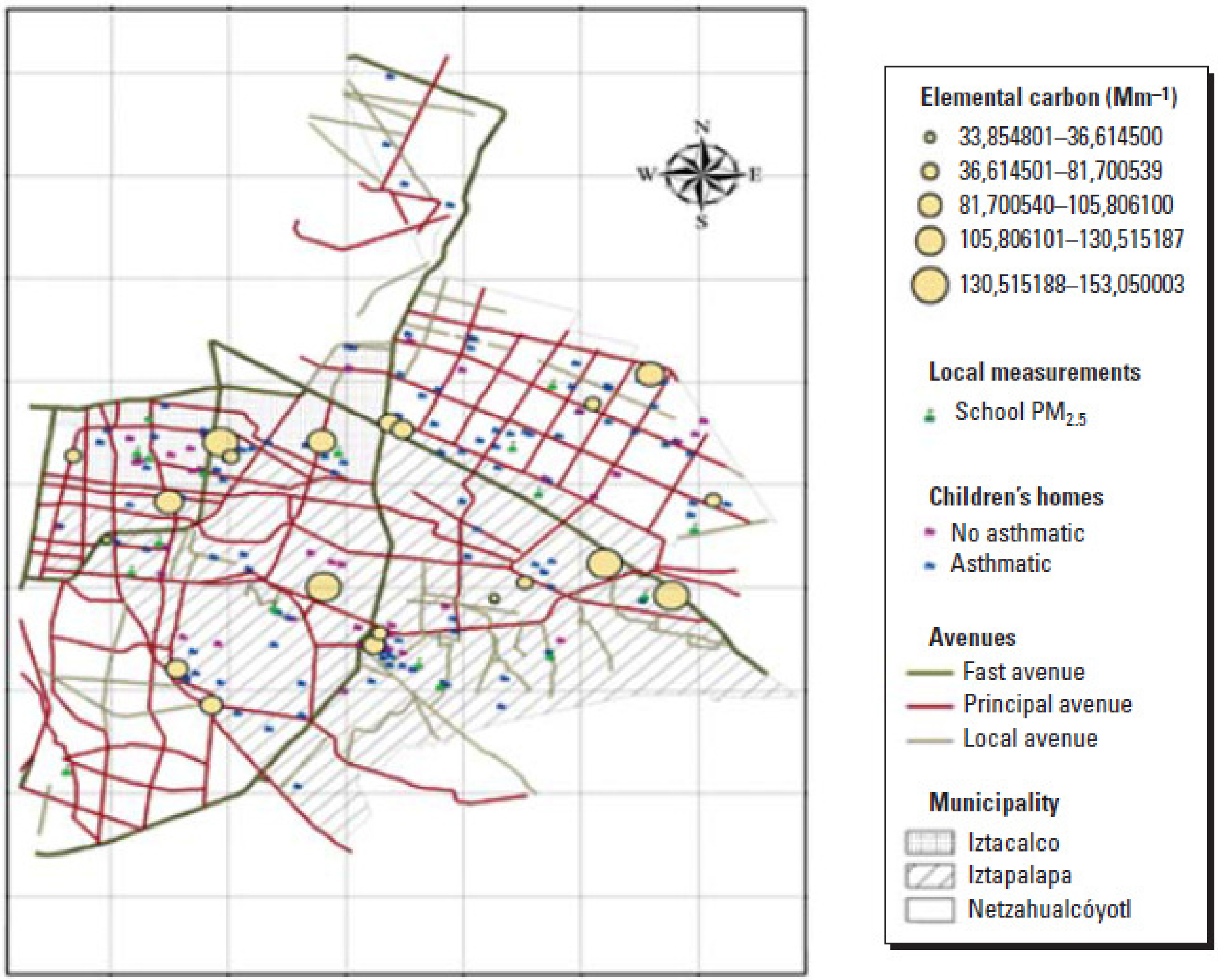
Short – term exposures to traffic-related emissions are associated with transient reductions in lung function





Short – term exposures to traffic-related emissions are associated with airway inflammation

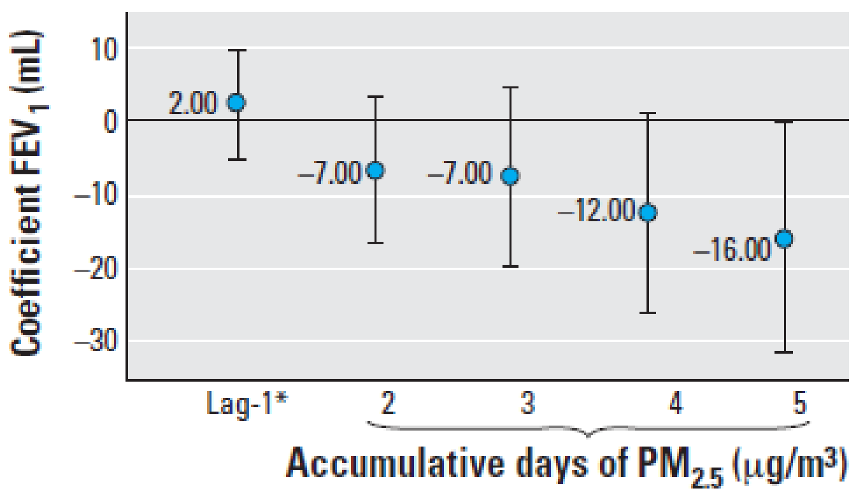
Air Pollution, Airway Inflammation, and Lung Function in a Cohort Study of Mexico City Schoolchildren



Barraza A, et al 2008; EHP

Table 4. Association [coefficients per increase in IQR (95% CI)] between exhaled NO, IL-8, pH of EBC, and lung function and air pollutants in nonasthmatic children living in Mexico City, 2003–2005.

Variable[a]	$PM_{2.5}$ (µg/m³)	NO_2 (ppb)
Fe_{NO}[a] (ppb)	0.89 (0.78 to 1.01)*	1.10 (0.99 to 1.23)*
IL-8[a] (pg/mL)	1.16 (1.00 to 1.36)**	1.15 (1.01 to 1.32)**
pH_EBC[a]	–0.05 (–0.14 to 0.04)	0.01 (–0.07 to 0.09)
FEV_1[b] (mL)	–21.0 (–42.3 to 0.38)*	–6.73 (–22.0 to 8.52)
FVC[b] (mL)	–29.0 (–52.8 to –4.35)**	–9.51 (–27.0 to 7.97)
$FEV_{25–75}$[b] (mL)	–20.0 (–69.0 to 29.0)	–12.1 (–47.0 to 22.7)



Lung function models were adjusted for sex, body mass index, previous day minimum temperature and chronological time. *p > 0.05, < 0.08. **p < 0.05 .

Traffic, Susceptibility, and Childhood Asthma

Table 1. Demographic characteristics and potential confounders or susceptibility factors.

Characteristic	No. (%)[a]
Child	
Sex	
Male	2,425 (51)
Female	2,295 (49)
Race	
North American Indian	44 (0.93)
Asian	170 (3.6)
Black	197 (4.2)
Hispanic white	2,617 (55)
Non-Hispanic white	1,682 (35)
Other	32 (0.67)

Environ Health Perspect 114:766–772 (2006).

Asthma and wheezing in relation to road proximity

Table 2. Association of asthma and wheeze with distance to a major road [OR (95% CI)].[a]

Major road distance (m)	No.[b]	Lifetime asthma	Prevalent asthma	Current wheeze
All participants				
> 300	2,058	1.00	1.00	1.00
150–300	1,193	0.92 (0.73–1.15)	1.04 (0.82–1.33)	1.02 (0.82–1.27)
75–150	778	1.06 (0.82–1.36)	1.33 (1.02–1.72)*	1.30 (1.02–1.66)*
< 75	713	1.29 (1.01–1.66)*	1.50 (1.16–1.95)**	1.40 (1.09–1.78)**
Long-term residents				
> 300	813	1.00	1.00	1.00
150–300	483	0.86 (0.59–1.24)	0.83 (0.56–1.21)	0.97 (0.69–1.38)
75–150	294	1.03 (0.68–1.56)	1.09 (0.71–1.66)	1.09 (0.73–1.62)
< 75	266	1.46 (0.98–2.17)	1.64 (1.10–2.44)*	1.67 (1.14–2.43)**

[a]Adjusted for age, sex, language of questionnaire, community, and race. [b]Total exposed in each category of distance to a major road. *$p < 0.05$; **$p < 0.01$.

Probability of asthma prevalence and distance to roads

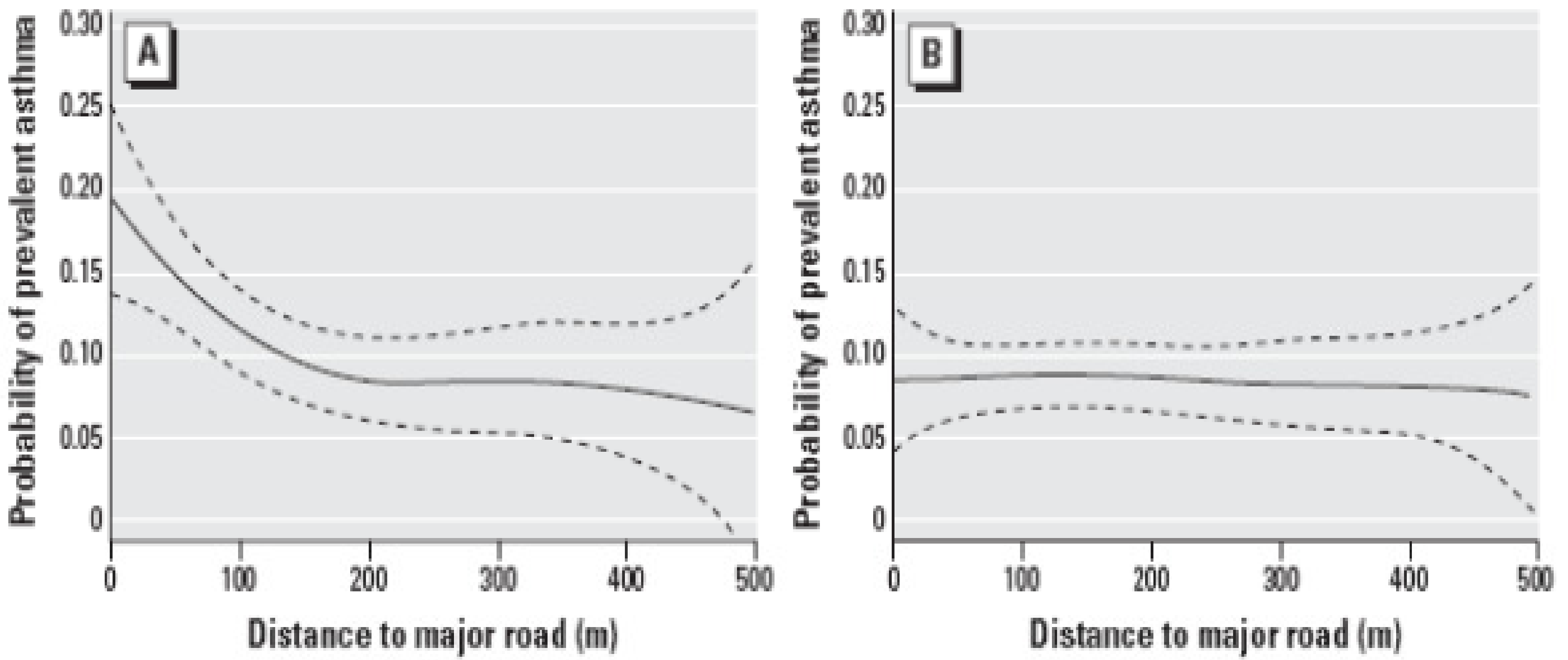
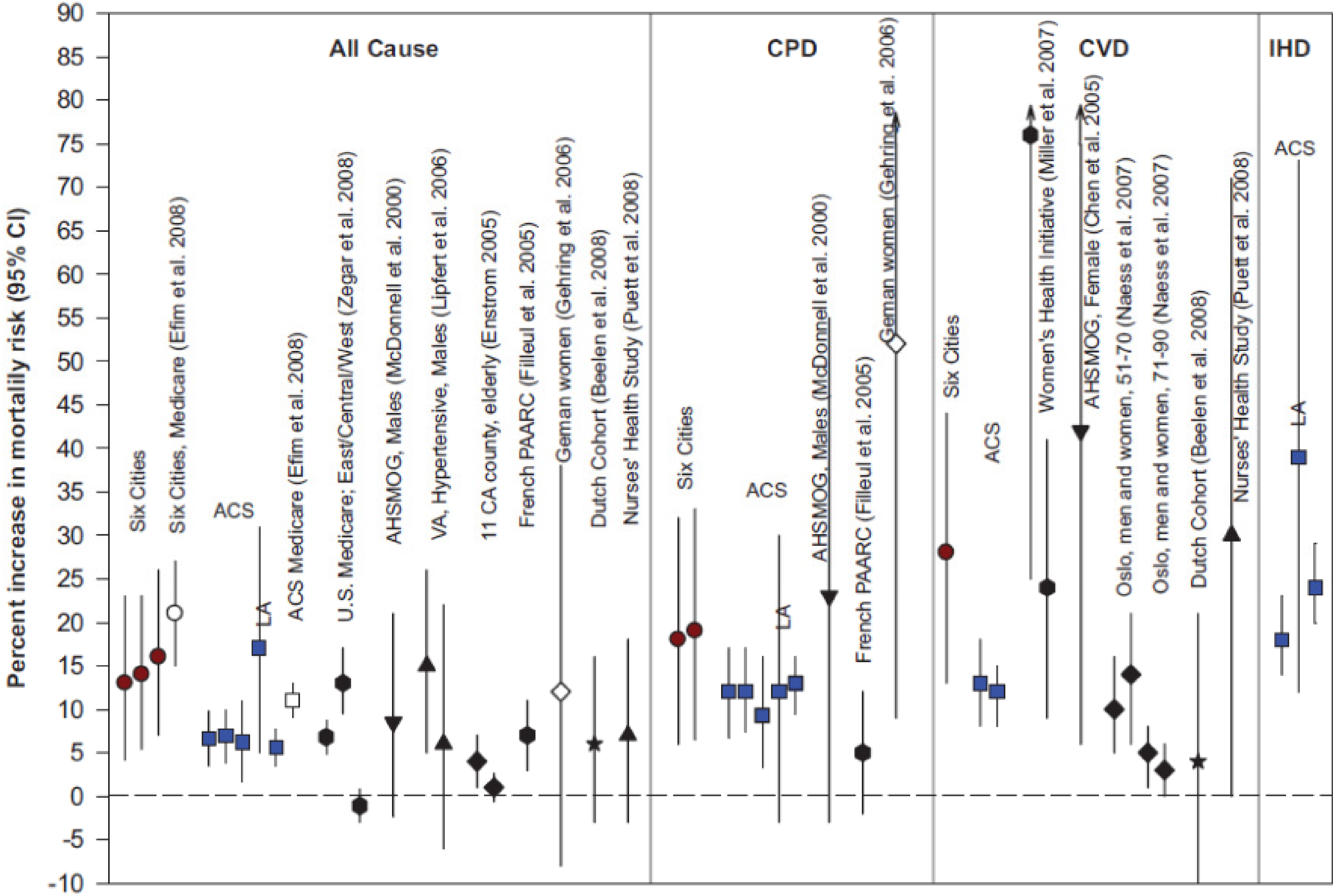
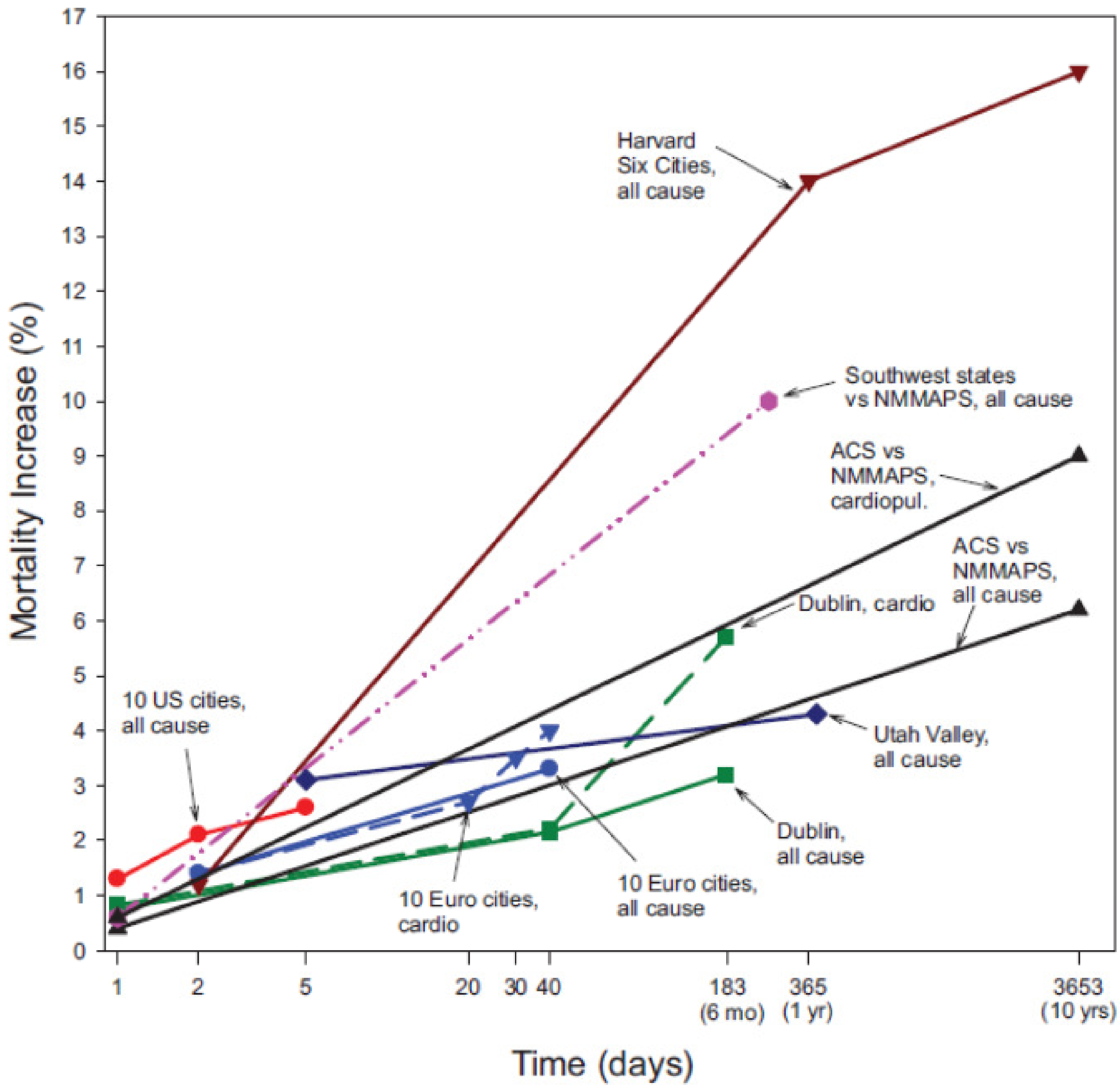


Figure 2. Prevalence of asthma by distance of residence to a major road within 500 m, among long-term (*A*) and short-term (*B*) residents with no family history of asthma. Dotted lines indicate 95% confidence interval.

Particulate matter pollution, a risk for multiple chronic diseases

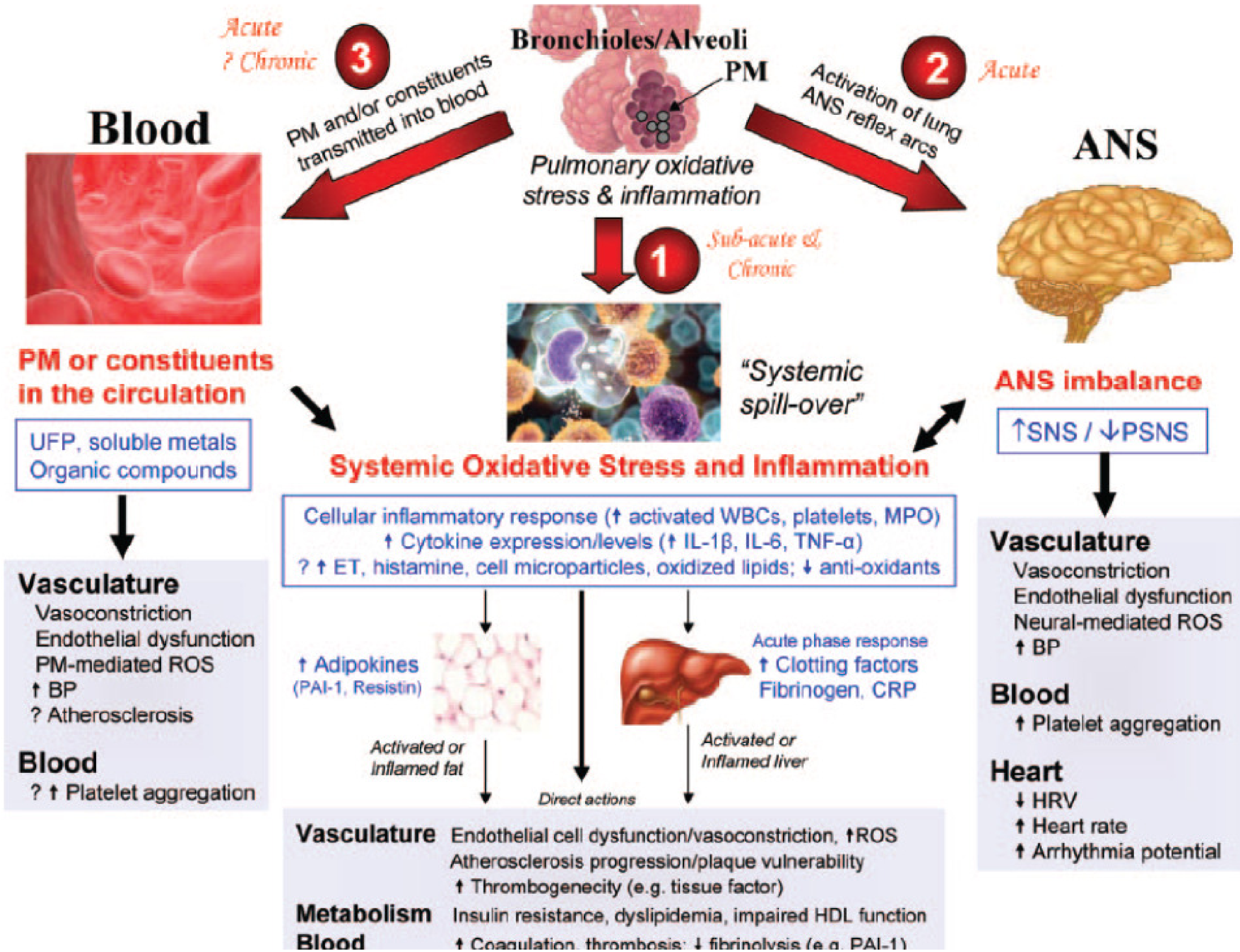


Brooks et al, Circulation AHA statement 2010

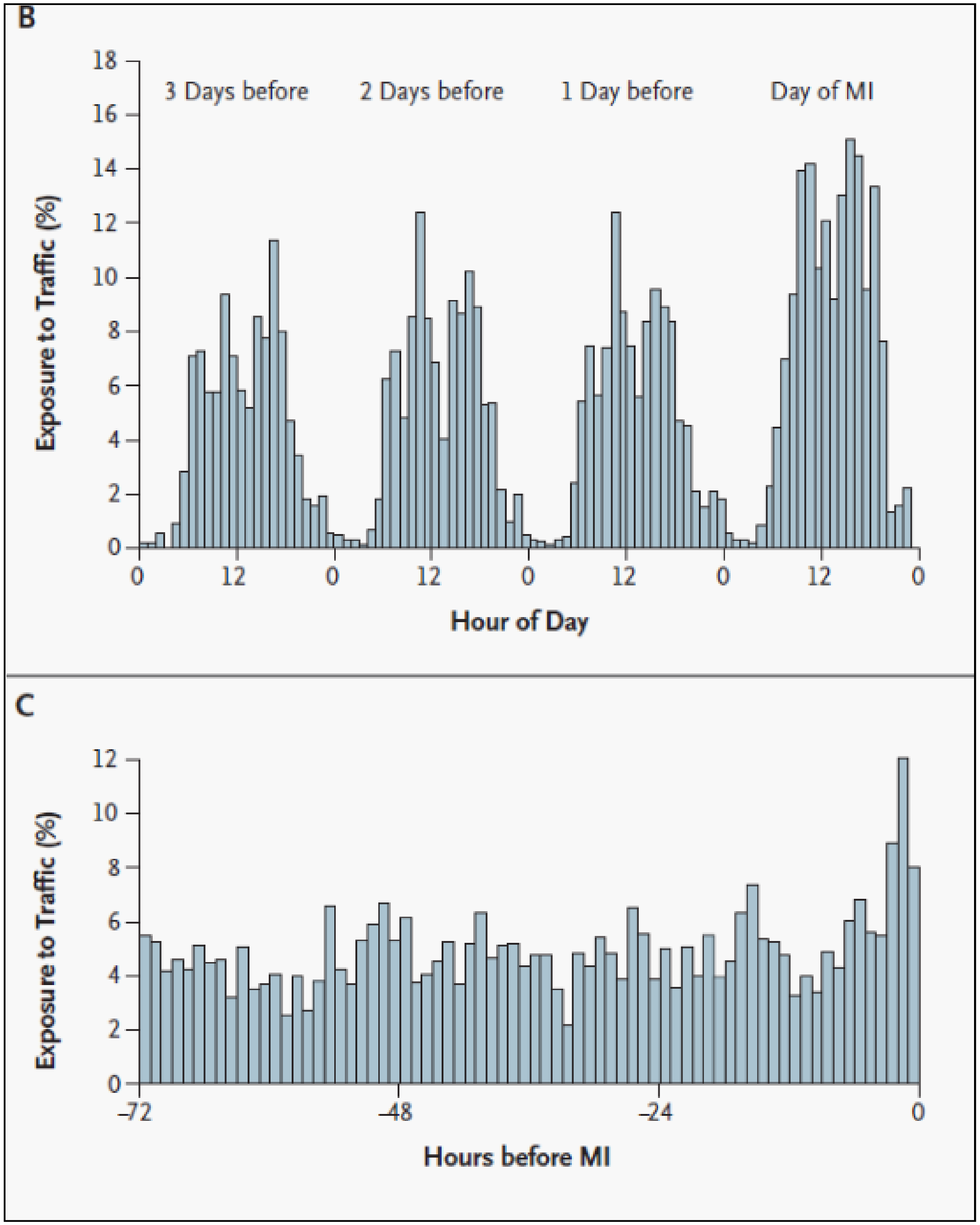


Mortality increase associated with a 10 μg/m^3 in PM2.5 or 20 μg/m^3 in PM10,
For different time scales

Brooks et al , Circulation 2010 AHA statement



Bronchioles/Alveoli
PM
Pulmonary oxidative stress & inflammation
Acute
? Chronic
3
PM and/or constituents transmitted into blood
2
Acute
Activation of lung ANS reflex arcs
1
Sub-acute & Chronic
Blood
ANS
PM or constituents in the circulation
UFP, soluble metals
Organic compounds
"Systemic spill-over"
ANS imbalance
↑SNS / ↓PSNS
Systemic Oxidative Stress and Inflammation
Cellular inflammatory response (↑ activated WBCs, platelets, MPO)
↑ Cytokine expression/levels (↑ IL-1β, IL-6, TNF-α)
? ↑ ET, histamine, cell microparticles, oxidized lipids; ↓ anti-oxidants
Vasculature
Vasoconstriction
Endothelial dysfunction
PM-mediated ROS
↑ BP
? Atherosclerosis
Blood
? ↑ Platelet aggregation
↑ Adipokines
(PAI-1, Resistin)
Acute phase response
↑ Clotting factors
Fibrinogen, CRP
Activated or Inflamed fat
Direct actions
Activated or Inflamed liver
Vasculature
Vasoconstriction
Endothelial dysfunction
Neural-mediated ROS
↑ BP
Blood
↑ Platelet aggregation
Heart
↓ HRV
↑ Heart rate
↑ Arrhythmia potential
Vasculature
Endothelial cell dysfunction/vasoconstriction, ↑ROS
Atherosclerosis progression/plaque vulnerability
↑ Thrombogenecity (e.g. tissue factor)
Metabolism
Insulin resistance, dyslipidemia, impaired HDL function
Blood
↑ Coagulation, thrombosis; ↓ fibrinolysis (e.g. PAI-1)



Recent traffic exposure to vehicular traffic is associated with increased ORs for acute myocardial infarction

691 AMI survivors from whom the onset of chest pain and traffic exposure could be quantified

Peters et al NEJM

ORs for AMI (vulnerable period vs control periods), by time spent in traffic

Type of Transportation and Hours before MI	No. of Subjects	Frequency of Exposure in Case Period on Day of MI (%)	Odds Ratio (95% CI)	P Value
Any means of transportation†				
Concurrent	585	8.0	1.50 (1.07–2.09)	0.02
1 hr	625	12.1	2.92 (2.22–3.83)	<0.001
2 hr	634	8.9	2.01 (1.49–2.72)	<0.001
3 hr	635	5.5	1.15 (0.79–1.66)	0.47
4 hr	638	5.6	1.27 (0.89–1.83)	0.19
5 hr	639	6.8	1.64 (1.17–2.30)	0.004
6 hr	640	6.1	1.34 (0.93–1.92)	0.11

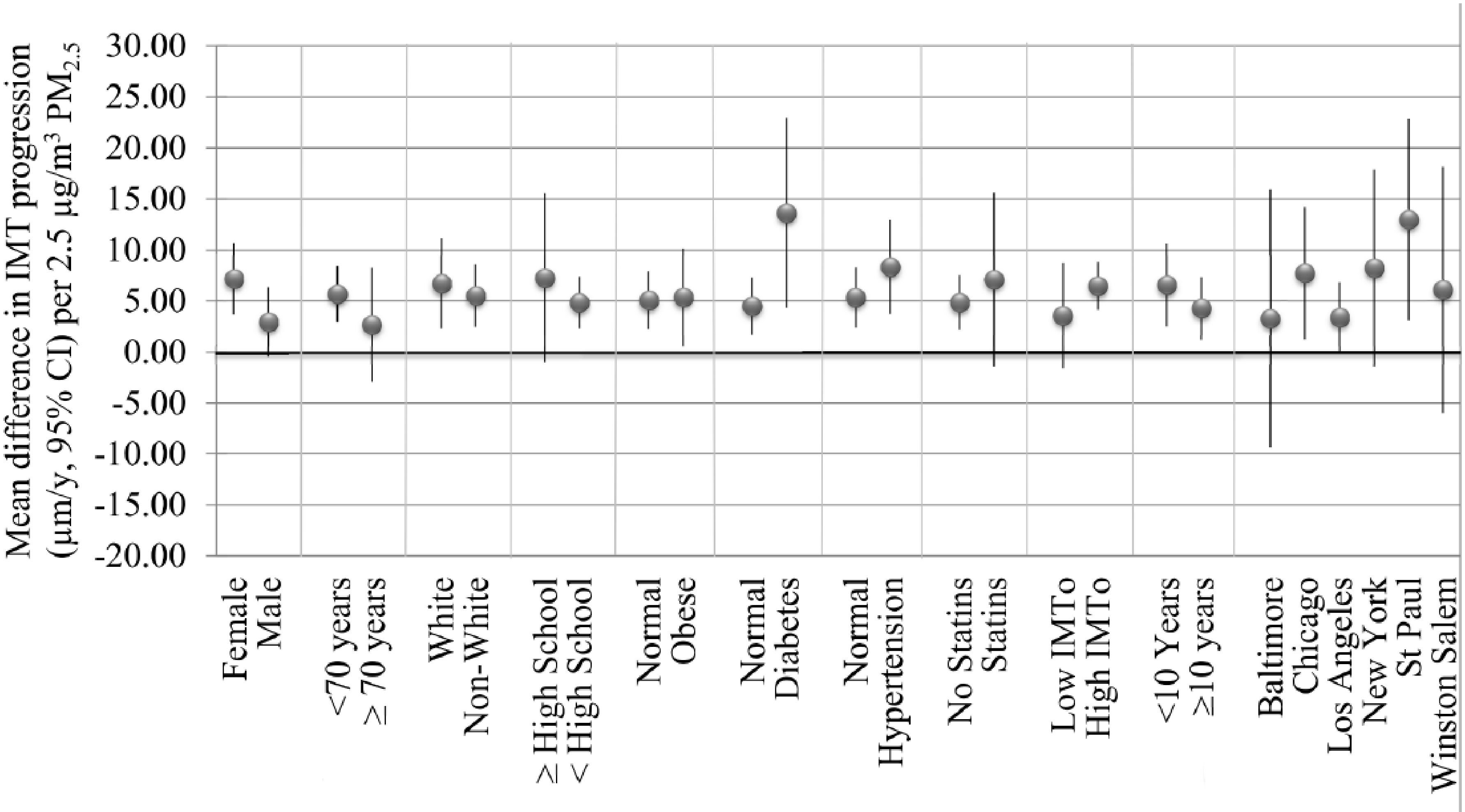
Peters et al, NEJM

Air pollution (PM2.5) and chronic peripheral vascular disease

Model	Overall Associations	Within-City Associations
Baseline IMT (μm) per 2.5 μg/m^3 of baseline $PM_{2.5}$		
Minimal adjustment	6.1 (2.6 to 9.6)	3.3 (−5.9 to 12.5)
Moderate adjustment	6.6 (3.1 to 10.2)	1.0 (−8.6 to 10.5)
Main model	6.3 (2.8 to 9.8)	0.4 (−9.1 to 9.9)
Extended adjustment	5.7 (1.5 to 9.8)	1.1 (−9.8 to 12.0)
Progression of IMT (μm/y) per 2.5 μg/m^3 of average follow-up $PM_{2.5}$		
Minimal adjustment	0.4 (−0.4 to 1.2)	4.8 (2.4 to 7.1)
Moderate adjustment	0.5 (−0.3 to 1.3)	4.9 (2.5 to 7.3)
Main model	0.4 (−0.4 to 1.2)	5.0 (2.6 to 7.4)
Extended adjustment	0.5 (−0.4 to 1.5)	4.4 (1.6 to 7.3)

Adar S, PLoS One 2014

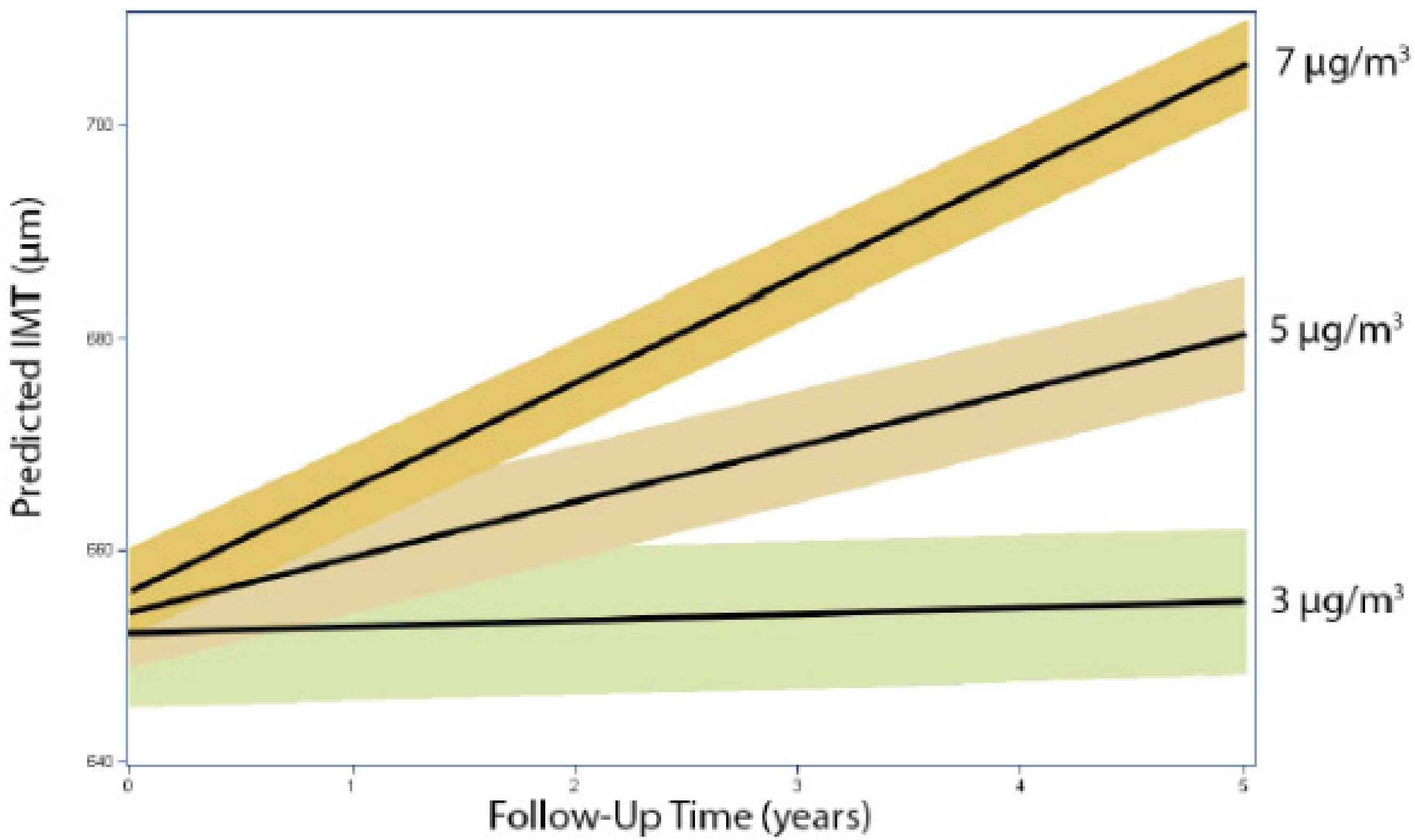
Fine particulate matter and chronic cardiovascular disease



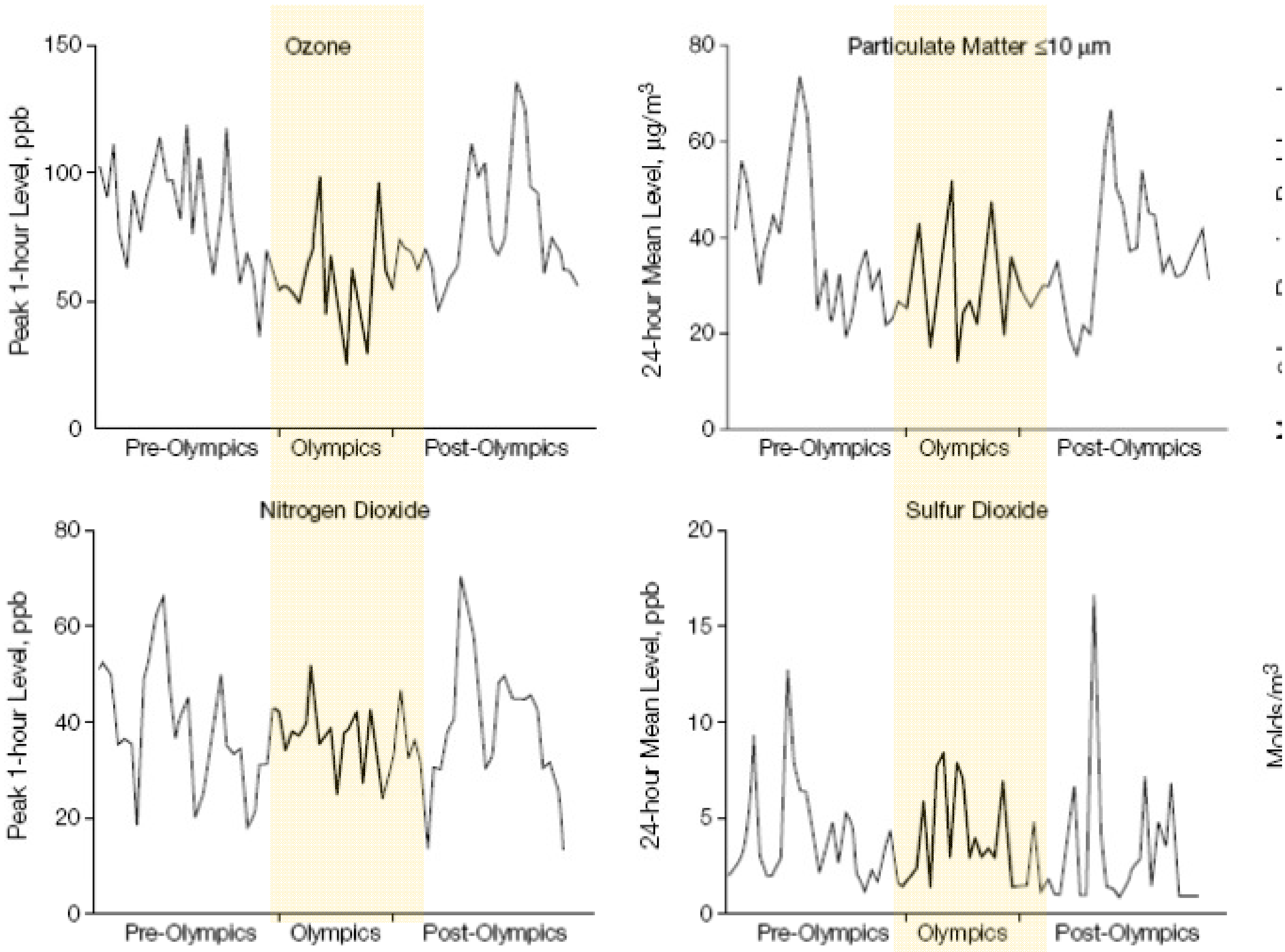
Mean difference in IMT progression (mm/y, 95% CI) per 2.5 µg/m^3 PM2.5 concentration averaged over follow-up in select stratified analyses controlled for metropolitan area.

Adar S, PLoS One 2014

Estimated IMT (95% CIs) over time at varying levels of average residential PM2.5 concentrations exceeding the city average during the follow-up period



Results are reported for concentration increments above the city mean with confidence intervals around the mean



Freeman, M JAMA 2001

Less pollution, less asthma morbidity

Table 2. Univariate and Adjusted Relative Risk of Acute Asthma Events During the 1996 Summer Olympic Games Compared With the 1996 Summertime Baseline Period*

Data Source	Univariate RR† (95% CI)	*P* Value	Adjusted RR‡ (95% Confidence Interval)	*P* Value
Georgia Medicaid claims file	0.61 (0.44-0.85)	.003	0.48 (0.44-0.86)	.006
Health maintenance organization	0.56 (0.31-1.02)	.06	0.58 (0.32-1.06)	.10
Pediatric emergency departments	0.91 (0.85-1.42)	.48	0.93 (0.71-1.22)	.69
Georgia Hospital Discharge Database	0.81 (0.54-1.23)	.34	0.71 (0.46-1.11)	.22

*RR indicates relative risk; CI, confidence interval. For definition of baseline period, see "Study Design" subsection of "Methods" section.

†Relative risk based on Poisson model (fraction of total acute care events with a primary diagnosis of asthma).

‡Time-series regression analysis was adjusted for day of week (weekday vs weekend) and minimum daily temperature (lagged 1 day to minimize serial correlation).

Freeman, M. JAMA 2001

When it comes to air pollution and its impact on human health

1. Not all air pollution exposures are the same
2. It matters who you are
3. Chronic and acute exposures lead to different outcomes; may involve different mechanistic pathways (Synergistic?)
4. No absolute safe level exists
5. Reducing emissions improves outcomes
6. Important questions remain; how and whom can we protect.