Secondhand and Thirdhand Smoke Exposures and Cardiovascular Outcomes

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Adult per capita consumption of cigarettes: USA 1900-1998
Global cigarette consumption by region

Trillions of cigarettes

- China
- Europe
- Americas
- S.E. Asia
- W. Pacific w/o China
- E. Mediterranean
- Africa

Ng et al. JAMA, 2014 and Tobacco Atlas
US secondhand smoke exposure

• 25.3% of nonsmokers
• 36.8% of nonsmokers in multi-unit housing
• 40% of children ages 3-7
• 70% of Black children

Global Secondhand smoke exposure

• 33% of male nonsmokers
• 35% of female nonsmokers
• 40% of children under 15
Smoking-attributable cardiovascular mortality in US

• Smokers 160,000 (36.8%)
  – 62% coronary heart disease
• Nonsmokers 41,951 (85%)
  – 69% heart disease
  – 16% stroke
What is cigarette smoke?

- ~90% Gases
- ~10% Particles and droplets of semivolatile organic compounds (tar)
- Sidestream comes from the tip
- Mainstream is what the smoker inhales
How much smoke does it take to cause heart disease?

Exposure from
Second hand cigarette smoke:
Stars, from 2006 Surgeon General Report and INTERHEART study
And air pollution:
Hex, from Women's Health Initiative cohort
Diamonds, from ACS cohort
Triangles, Harvard Six Cities cohort

Exposure from smoking
≤3, 4-7, 8-12, 13-17, 18-22, and 23+ cigarettes/day

From Pope et al., 2009 Circulation
Mechanisms that contribute to vascular disease

- Inflammation
- Sympathetic Nervous System
- Oxidative Stress
- Endothelial Function
- Myocardial Infarction
- Thrombus Formation

SFS 2017
Endothelium

- Lines every blood vessel
- $6 \times 10^{13}$ cells
- Estimated surface area: $1-7 \text{ m}^2$
- Anti-stick/clot
- Vasodilation
Atherosclerosis I: blocked pipe
Atherosclerosis II: It’s alive!

Endothelial dysfunction

Monocyte infiltration and differentiation

Migration and proliferation of fibroblasts and vascular smooth muscle cells
Vascular disease affects more than just the heart

- Heart attack
- Stroke
- Peripheral Arterial Disease
- Chronic kidney disease
Flow-Mediated Dilation of the Brachial Artery Measured by Ultrasound
30 minute exposure to 350 μg/m³ fresh sidestream smoke causes decrease in FMD

* p 0.05 versus baseline of same day (exposure condition) Heiss et al. 2008 JACC
30 minutes exposure at 350 µg/m³

- Decreases ability of arteries to change diameter in response to increased pressure or flow rate
- Increases concentration of cell debris in blood
- Causes circulating repair cells to multiply, but decreases their ability to move
- Increases concentration of inflammatory proteins in blood

Heiss et al, 2008
SHS exposure reduces FMD at 150 µg/m³
SHS Conclusions

• Very small changes in particle concentrations in the air have very large health effects
• Combustion particle exposure has a non-linear dose-response
• Vascular disease affects more than the heart
What is Thirdhand cigarette smoke?  
**The 3 R’s**

Chemicals in cigarette smoke that:

• *Remain* on surfaces and in dust
• *Re-emit* back into the gas phase
• *React* with other chemicals in the environment to make new chemicals
Remain

- Tar chemicals stick to surfaces before they can be removed by ventilation
  - Walls, carpet, dust, people...
- Tar absorbs into porous materials
- Tar contains nicotine and many toxins and carcinogens
  - Nitrosamines
  - Polycyclic aromatic hydrocarbons
- Persistence increases exposure time
Thirdhand Smoke Emits Particles
Particle output

mg/m³

Time

9:30 9:45 10:00 10:15 10:30 10:45 11:00
Something coming out before start the smoking machine
“Secondary” particles from Thirdhand Smoke
Secondhand Smoke Generation Mode

Thirdhand Smoke Deposition Mode

Thirdhand Smoke Exposure Mode
Breathing THS increases cotinine

Hours

ng/ml

Clean Air median

THS

0 3.5 10 20 22
Preliminary Data from N=112 Low-Income Units in San Diego County: Distribution of Nicotine Surface Concentrations

- "Typical" San Diego Nonsmoker Homes: 64% Elevated Levels
  - Mdn = 2.0 µg/m²
- Greater than 2x higher than typical San Diego nonsmoker homes: 50%
- Greater than 10x: 17% of homes
- Greater than 100x: 7% of homes
- Greater than 1,000x: 2% of homes

Level of detection:
- Median Nicotine Concentration

<table>
<thead>
<tr>
<th>Smoking Ban Conditions</th>
<th>Nicotine Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking ban</td>
<td>3,926 µg/m²</td>
</tr>
<tr>
<td>Smoking ban; past smoking ≥3 years ago</td>
<td>2,586 µg/m²</td>
</tr>
<tr>
<td>Visitors may smoke</td>
<td>550 µg/m²</td>
</tr>
<tr>
<td>No smoking ban</td>
<td>212 µg/m²</td>
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</tbody>
</table>

≥1 µg/m²: 64% Elevated Levels
≥3 µg/m²: 39% eligible for cleaning
THS Conclusions

• About 10% of the smoke of every cigarette lingers for an extended exposure
• Thirdhand smoke is toxic and carcinogenic
• Thirdhand smoke on surfaces emits constant low levels of particles and chemicals
• Breathing thirdhand smoke causes detectable increases in the levels of nicotine in the body
THS health effects in mice

- Slower wound healing
- Lung inflammation
- Hyperactivity
- Insulin resistance
- Metabolic syndrome
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E-Cigarettes reduce FMD in healthy young people

<table>
<thead>
<tr>
<th>% FMD</th>
<th>Nonsmokers</th>
<th>Smokers</th>
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</thead>
<tbody>
<tr>
<td>Before Smoking Cigarette</td>
<td>7.83</td>
<td>5.62</td>
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<tr>
<td>After Smoking Cigarette</td>
<td>3.96*</td>
<td>2.82*</td>
</tr>
<tr>
<td>Before Using E-Cigarette</td>
<td>7.38</td>
<td>5.88</td>
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<tr>
<td>After Using E-Cigarette</td>
<td>4.56*</td>
<td>3.99*</td>
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Carnavale et al. 2016