Portable Air Cleaners, Cardiovascular Health, and Fetal Growth: Results from Randomized Studies in Canada and Mongolia

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Presentation Overview

- Two randomized studies of portable HEPA filter air cleaners and health:
  - Rural Canadian community
    - Moderate concentrations from **wood stoves**
    - 7-day intervention, healthy adults
    - **Cardiovascular outcomes**
  - City in a developing country (Mongolia)
    - High concentrations from **coal stoves**
    - 7-month intervention, pregnant women
    - **Fetal growth indicators**
Portable Air Cleaners and Wood Smoke

• Smithers, British Columbia
  – Population ~5,300
  – At the time, 63% of homes in the region used wood as primary heating fuel.

Photo courtesy of Ben Weinstein
Study Design

Single-blind randomized crossover study design:

- 43 healthy adults (mean age: 43 years)
- Honeywell 50300 in living room; 18150 in bedroom
- Two consecutive 7-day monitoring periods
- Measures of oxidative stress, systemic inflammation, and endothelial (blood vessel) function
Results

- Air pollution concentrations:
  - PM$_{2.5}$ infiltration efficiency: ↓41% (0.34 → 0.20)
  - Indoor PM$_{2.5}$ concentration: ↓59% (11.2 → 4.6 µg/m$^3$)
  - Indoor levoglucosan concentration: ↓74% (127 → 33 ng/m$^3$)

- Health effects:
  - ↑ blood vessel function (reactive hyperemia index)
  - ↓ systemic inflammation (C-reactive protein)
  - No changes in oxidative stress markers

Allen et al., Am J Respir Crit Care Med, 2011
Rationale

- Meta-analyses of observational studies report ~10-20 gram decreases in mean birth weight per 10 µg/m³ PM$_{2.5}$
Rationale

More than 90% of people worldwide live in areas exceeding the WHO Guideline for healthy air. More than half live in areas that do not even meet WHO’s least-stringent air quality target.

Figure 2. Annual average PM$_{2.5}$ concentrations in 2017 relative to the WHO Air Quality Guideline.

- Emissions reductions should be the goal, but...
- Household-level interventions may mitigate risks in the near term
- Pregnancy represents a well-defined time period for intervention, with potential benefits over the life course

Ulaanbaatar, Mongolia

- Population ~ 1.3 million
- Air pollution:
  - Rapid population growth
  - Cold winters
  - Topography
  - Coal combustion

Allen et al., *Air Qual Atmos Health*, 2013
In Ulan Bator, winter stoves fuel a smog responsible for one in 10 deaths

Life in the Most Polluted Capital in the World

By Joseph Hincks | Photographs by Zhang Chi for TIME | Video by Zhang Chi, Aria Chen and Arpita Aneja
March 23, 2018

Burning Coal for Survival in the World’s Coldest Capital
Study Design

• **Randomized controlled trial**
  – Intervention group received 1-2 HEPA filter air cleaners for use in homes, and control group received no air cleaners (single blind; participants were aware of intervention status)
  – Coway AP-1009CH air cleaner, CADR (smoke) = 150

• **Study sample:**
  – Non-smoking, ≥ 18 years, ≤ 18 weeks pregnancy, single gestation pregnancy, residing in apartments

• **Sample size:** 540 participants recruited

• **Data collection period:** January 2014 to December 2015
Data Collection

Conception

~11 weeks

Air cleaner deployed (intervention homes)

Delivery

~31 weeks

7-day PM$_{2.5}$ measurement

Birth measurements (weight, length, head circumference)
Air Cleaner Impact on PM$_{2.5}$

7-day average PM$_{2.5}$ concentrations

-29% (-37, -21%)

Barn et al., Sci Total Environ, 2018
Air Cleaner Impact on PM$_{2.5}$

7-day average PM$_{2.5}$ concentrations

<table>
<thead>
<tr>
<th>Season</th>
<th>Control homes</th>
<th>Intervention homes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter (Dec-Feb)</td>
<td>-36% (-49, -20%)</td>
<td></td>
</tr>
<tr>
<td>Spring (Mar-May)</td>
<td>-35% (-48, -19%)</td>
<td></td>
</tr>
<tr>
<td>Summer (Jun-Aug)</td>
<td>-18% (-30, -4%)</td>
<td>-31% (-43, -18%)</td>
</tr>
<tr>
<td>Fall (Sep-Nov)</td>
<td>-31% (-43, -18%)</td>
<td></td>
</tr>
</tbody>
</table>

Barn et al., Sci Total Environ, 2018
Air Cleaner Impact on PM$_{2.5}$

7-day average PM$_{2.5}$ concentrations

First week of deployment

-40% (-48, -31%)

~ 5 months after deployment

-15% (-27, 0%)

Barn et al., Sci Total Environ, 2018
Trial Profile

Randomized (n=540)

Allocated to control (n=272)
- Received allocated control (n=267)
- Did not receive allocated control (n=5)

Lost to follow up (n=19)
- 13 withdrew consent
- 6 moved out of study area

Followed until the end of pregnancy (n=253)

Excluded (n=30)
- 24 spontaneous abortions
- 5 stillbirths
- 1 chromosomal abnormality

Analysed (n=223)
- 222 live births
- 1 neonatal death

Allocated to intervention (n=268)
- Received allocated intervention (n=265)
- Did not receive allocated intervention (n=3)

Lost to follow up (n=9)
- 3 withdrew consent
- 6 moved out of study area

Followed until the end of pregnancy (n=259)

Excluded (n=19)
- 10 spontaneous abortions
- 8 stillbirths
- 1 chromosomal abnormality (also a neonatal death)

Analysed (n=240)
- 237 live births
- 3 neonatal deaths

Barn et al., Environ Int, 2018
# Select Cohort Characteristics

<table>
<thead>
<tr>
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<th>Control (n = 223)</th>
<th>Intervention (n = 240)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Median (25%-75%)</td>
<td>or N (%)</td>
</tr>
<tr>
<td></td>
<td>or N (%)</td>
<td></td>
</tr>
<tr>
<td>Mother’s age at enrollment, yr</td>
<td>28 (25 – 33)</td>
<td>30 (25 – 33)</td>
</tr>
<tr>
<td>Gestational age at enrollment, weeks</td>
<td>11 (9 – 12)</td>
<td>11 (9 – 13)</td>
</tr>
<tr>
<td>Mother completed university</td>
<td>179 (80%)</td>
<td>191 (80%)</td>
</tr>
<tr>
<td>Married / common-law</td>
<td>184 (83%)</td>
<td>191 (80%)</td>
</tr>
<tr>
<td>Pre-pregnancy BMI, kg/m²</td>
<td>21.7 (19.6 – 23.9)</td>
<td>21.4 (19.8 – 24.0)</td>
</tr>
<tr>
<td>Smoked at any time during pregnancy</td>
<td>19 (9%)</td>
<td>20 (8%)</td>
</tr>
<tr>
<td>Lived w/ smoker at any time during pregnancy</td>
<td>112 (50%)</td>
<td>115 (48%)</td>
</tr>
<tr>
<td>Caesarean delivery</td>
<td>88 (39%)</td>
<td>86 (36%)</td>
</tr>
<tr>
<td>Female child</td>
<td>108 (48%)</td>
<td>109 (45%)</td>
</tr>
<tr>
<td>Birth weight, grams</td>
<td>3450 (3150 – 3800)</td>
<td>3550 (3200 – 3800)</td>
</tr>
</tbody>
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Barn et al., *Environ Int*, 2018
Unexpected Intervention Effects

• The intervention was associated with:
  – A lower risk of spontaneous abortion:
    \[ \text{OR} = 0.38 \ (95\% \ CI: \ 0.18, \ 0.82) \]
  – A higher risk of preterm birth:
    \[ \text{OR} = 2.37 \ (95\% \ CI: \ 1.11, \ 5.07) \]

• The intervention may have enabled fetuses to survive long enough to be born preterm

Barn et al., Environ Int, 2018
Intervention Effects on Fetal Growth

- The intervention was not significantly associated with average birth weight among all births: 18 g (95% CI: -84, 120 g)
  - After adjusting for differences in pre-term birth, the intervention was associated with an increase in mean birth weight: 84 g (95% CI: -1, 170 g)
- Among full-term births, the intervention was associated with an increase in mean weight: 85 g (95% CI: 3, 167 g)
Summary

• Short-term use of portable HEPA filter air cleaners may improve cardiovascular health indicators
  – Supported by several more recent studies
  – Implications for effects in other systems in the body

• Long-term use reduced concentrations in a high-pollution setting, but efficacy decreased over time
  – “Air cleaner fatigue” – noise, concerns about electricity costs

• Some evidence of improved fetal growth among women who used air cleaners during pregnancy

• When possible, our goal should be to reduce emissions
  – Household interventions may mitigate risks
  – Pregnancy is a well-defined time to intervene
Thank You

- Study participants
- Research staff
- Dr. Prabjit Barn
- Funding agencies