Controlled human exposure to fine and ultrafine particles from indoor sources – changes in lung function and blood pressure

Vanessa Soppa
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EPIA: Effects of Particles from Indoor Activities

Background

- Fine particulate matter (PM) is linked to cardiovascular diseases, allergic & inflammatory conditions of the lung
- To date, most studies investigate ambient particles
- In the developed world, humans spend most of their time indoors
- Several indoor activities emit high amounts of fine and ultrafine particles
Hypothesized biological pathways of particulate matter

**Autonomic nervous system imbalance**
- Cognitive function test
- HRV

**PM**
- nasopharynx
- bronchioles/alveoli

**Local inflammation**
- Nasal lavage: markers of inflammation
- Cytokines IL-6, IL-8; CRP; MPO

**Local inflammation and oxidative stress**
- FeNO-test: exhaled NO
- **Lung function test: MEF 25-75%, FVC, FEV1**
- Soluble PM constituents transmitted into blood
- Systemic spill over
- Blood

**Systemic inflammation and oxidative stress**
- Blood markers: IL-6, IL-8, hs-CRP (inflammation), 8-Isoprostanes (oxidative stress), ICAM-1 (endothelial function), fibrinogen (coagulation)

Cardiovascular System:
- PWA, PWV, endothelial dysfunction,
- increase in blood pressure
Objective

• To investigate whether exposure to particles from indoor activities leads to health-related changes in healthy volunteers
EPIA: Design

- Sham-controlled cross-over exposure study with 55 healthy volunteers
- Temperature-controlled exposure chamber
- Two hour exposure
  - Candles (C)
  - Toasting bread (TB)
  - Frying sausages (FS)
  - Sham exposure: „Air refresher“ (Room Air)
- Exposure on the same day and time of the week at least 2 weeks apart

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Exposure Measurements
Continuous measurements during each exposure session
Calculation of personal 2h-exposure during session

- **Size-specific particle number** concentration PNC (FMPS and APS)
- **Particle mass** concentrations for PM$_1$, PM$_{2.5}$, PM$_{10}$, (FMPS and gravimetric)
- **Alveolar deposited surface area** concentration (NSAM)
- **Chemical composition** (AMS)
- **EC/OC** Analyser
- CO Monitor
- Particle collection for tox
## Health Outcomes

<table>
<thead>
<tr>
<th></th>
<th>Pre-exposure (baseline)</th>
<th>During exposure</th>
<th>Directly after exposure</th>
<th>2 h after exposure</th>
<th>4 h after exposure</th>
<th>24 h after exposure</th>
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</thead>
<tbody>
<tr>
<td>Diary</td>
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<tr>
<td>Nasal lavage</td>
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<tr>
<td>FeNO-Test</td>
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<td>x</td>
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<tr>
<td>Blood draw</td>
<td>x</td>
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<td>x</td>
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<tr>
<td><strong>Blood pressure</strong></td>
<td><strong>x</strong></td>
<td><strong>x</strong></td>
<td><strong>x</strong></td>
<td><strong>x</strong></td>
<td><strong>x</strong></td>
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<tr>
<td><strong>Lung function</strong></td>
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<td>x</td>
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<tr>
<td>PWA</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>PWV and HRV</td>
<td>x</td>
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<td>x</td>
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<tr>
<td>PEG-Board-Test</td>
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</tbody>
</table>

Lung function: Spirometry (ndd Easy One)  
Blood pressure: automatic ambulatory blood pressure monitor (M10-IT; Omron Healthcare GmbH)
Statistical Analysis

• Linear mixed regression analysis with random participant intercept
• Separate analysis for each exposure
• Independent variables: personal cumulative exposure to the particle metrics size-specific particle mass, particle number and surface area during the exposure sessions
• Dependent variable: intra-individual difference to \( t0 \)
• Interaction term: exposure*time point
• Covariates: age, height, sex, temperature, humidity, travel time and means of transportation (full model).
## Results – Study population (N=55)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Measure</th>
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</thead>
<tbody>
<tr>
<td>Age, years (mean±SD)</td>
<td>33.0 (16.6)</td>
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<tr>
<td>Born in Germany, n (%)</td>
<td>35 (64.8)</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>28 (50.9)</td>
</tr>
<tr>
<td>Weight, kg (mean±SD)</td>
<td>72.6 (14.0)</td>
</tr>
<tr>
<td>Height, cm (mean±SD)</td>
<td>174.3 (9.2)</td>
</tr>
<tr>
<td>Economic activity, n (%)</td>
<td></td>
</tr>
<tr>
<td>High School Graduation</td>
<td>42 (79.3)</td>
</tr>
<tr>
<td>Employed</td>
<td>25 (47.2)</td>
</tr>
<tr>
<td>Smoking status, n (%)</td>
<td></td>
</tr>
<tr>
<td>Ex-smoker</td>
<td>3 (5.6)</td>
</tr>
<tr>
<td>Never-smoker</td>
<td>51 (94.4)</td>
</tr>
<tr>
<td>History of allergy, n (%)</td>
<td></td>
</tr>
<tr>
<td>Allergy</td>
<td>17 (32.7)</td>
</tr>
<tr>
<td>Transport mode, n (%)</td>
<td></td>
</tr>
<tr>
<td>Car</td>
<td>106 (40.3)</td>
</tr>
<tr>
<td>Public transportation</td>
<td>145 (55.1)</td>
</tr>
<tr>
<td>On foot</td>
<td>2 (0.8)</td>
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</tbody>
</table>
## Exposure characterization

<table>
<thead>
<tr>
<th></th>
<th>Room Air</th>
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</thead>
<tbody>
<tr>
<td><strong>PM$_{10}$ [µg/m$^3$]</strong></td>
<td>6.2</td>
<td>56 - 84</td>
<td>87 - 126</td>
<td>100 – 279</td>
</tr>
<tr>
<td><strong>PM$_{2.5}$ [µg/m$^3$]</strong></td>
<td>4.7</td>
<td>53 - 81</td>
<td>63 - 82</td>
<td>84 – 235</td>
</tr>
<tr>
<td><strong>PM$_1$ [µg/m$^3$]</strong></td>
<td>3.2</td>
<td>50 – 79</td>
<td>38 – 80</td>
<td>71 - 208</td>
</tr>
<tr>
<td><strong>PNC UFP [10$^3$/ml]</strong></td>
<td>3.0</td>
<td>1,610 – 2,670</td>
<td>900 – 1,560</td>
<td>310 - 610</td>
</tr>
<tr>
<td><strong>PSC [µm$^2$/cm$^3$]</strong></td>
<td>23</td>
<td>2,201 – 3,840</td>
<td>1,769 – 3,780</td>
<td>1,325 – 3,456</td>
</tr>
</tbody>
</table>
Chemical Composition

– Candle burning:
  • Gases: Acetaldehydes, aceton < 1 ppm
    CO < detection limit
  • Particles: Organic hydrocarbons, Nitrates
    OC >> EC (7%)

– Frying sausages:
  • Gases: Acetaldehydes, propanoic acid ~ 25 ppm
  • Particles: Organic hydrocarbons,
    OC

– Toasting bread:
  • Gases: Ethanol, Acetaldehydes << 1 ppm
  • Particles: Organic hydrocarbons
    OC (EC < 1%)
Candle burning *

- Mean effect estimates & 95% Confidence Interval (CI)
- Associated for changes (difference) with an increase in particulate metrics post 4 h and 24 h post exposure
- Associated for different exposure scenarios for PMC, PSC and PNC
- Changes refer to an increase of 10 µg/m³ (PMC), 100 µm²/cm³ (PSC) and 10,000 number/cm³ (PNC)

*Adjusted for source
Lung function $(\text{FEV}_1)$

Frying sausages*

- Mean effect estimates & 95% Confidence Interval (CI)
- Associated for changes (difference) with an increase in particulate metrics post 4 h and 24 h post exposure
- Associated for different exposure scenarios for PMC, PSC and PNC
- Changes refer to an increase of 10 $\mu$g/m$^3$ (PMC), 100 $\mu$m$^2$/cm$^3$ (PSC) and 10,000 number/cm$^3$ (PNC)

*Adjusted for source
Blood pressure (systolic BP)

- Mean effect estimates & 95% Confidence Interval (CI)
- Associated for changes (difference) with an increase in particulate metrics during, post, post 2 h, post 4 h and 24 h post exposure
- Associated for different exposure scenarios for PMC and PSC
- Changes refer to an increase of 10 $\mu g/m^3$ (PMC) and 100 $\mu m^2/cm^3$ (PSC)
Blood pressure (systolic BP)

Toasting bread

- Mean effect estimates & 95% Confidence Interval (CI)
- Associated for changes (difference) with an increase in particulate metrics during, post, post 2 h, post 4 h and 24 h post exposure
- Associated for different exposure scenarios for PMC and PSC
- Changes refer to an increase of 10 µg/m³ (PMC), and 100 µm²/cm³ (PSC)
Summary and Discussion

- Use of novel metric „surface area“
- PSC was dominated by particles between 100-1000 nm in diameter
- Particles mostly organic hydrocarbons, little soot
- Effects differed across sources:
  - Candle burning & frying sausages showed clearest effects on lung function, associations strongest for particle mass concentration
  - After candle burning and toasting bread elevated blood pressure
    - Associations strongest for particle mass concentration and particle surface concentration, in particular 2 & 4 hours after exposure
    - Stronger effects for systolic blood pressure
    - No effects after frying sausages

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Limitations

• Two-hour exposure short, but exposures comparatively high (higher than in real-life daily circumstances)
  – Nevertheless well below the concentrations that are typically present in controlled exposure studies of outdoor air pollutants (PMC: 200-300 g/m$^3$ PM2.5 (Cosselman et al 2012; Mills et al 2007)).

• Blinding not possible

• Participants healthy, no vulnerable populations included (i.e. asthmatics)
Conclusions

- Examined sources showed large differences regarding their mass-, number- and surface-concentration as well as their chemical composition.

- Two-hour exposures to high concentrations of fine particles from common indoor sources are variably associated with small decreases in lung function and increases in arterial blood pressure in healthy adults.

- The effects of the examined sources varied, possibly due to the physical and chemical composition of the emitted particles. General transfer to sources of indoor particles is not possible.

- The observed short-term effects are important because they point to the activation of similar biological mechanisms as short-term exposures to outdoor particles.
Thanks to …

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