Air Pollution Exposure and Health Impacts of Cyclists Along Two Bicycle Routes in Vancouver

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Benefits of active transportation:

- May help reduce excess weight
  - Canadian adults: 37% overweight, 24% obese
- Decreased stress and injury susceptibility
- Chronic disease prevention (cancer, type 2 diabetes, CHD)

Cycling decreases:

- Traffic congestion
- Air pollution & GHG emissions

1 Canadian Health Measures Survey (2007-2009)
Other research:

Air pollution measured in Vancouver\(^1\)
  - Airborne particle levels varied according to:
    - Proximity to major roadways
    - Heavy traffic volumes

The Netherlands\(^2\)
  - 59% higher ultrafine particle levels on high-traffic vs. low-traffic routes

\(^1\)Thai et al. 2007; \(^2\)Strak et al. 2010
Many exist- gases such as benzene, SO₂, NOₓ; particles of different sizes

Major sources include road traffic (fossil fuel combustion), but also industry, natural sources

Ex. PM₁₀ are particles! 10µm in aerodynamic diameter
We measured particulate matter—“PM”, in a number of size ranges (PM$_{10}$, PM$_{2.5}$, PM$_{1}$, UFP- PM$_{0.02-1}$)

*PM$_{10}$ = 10 000 nm*
Cyclists have breathing rates 2 – 4 x higher than those of car passengers\(^1,2\)

Cyclists are close to the pollution source"

Pollution exposure \(\times\) Breathing = Intake

Limited research on real-life intake, dose & health impacts

Zuurbier et al. 2009; Int Panis et al. 2010
The Cycling, Air Pollution and Health Study

- 38 healthy, young adults
- Each rides: 1 hr downtown & 1hr residential route (random order)
- Before/after ride:
  - 3 health tests
- During ride (6 secs):
  - Heart rate, power output
  - Location (GPS)
  - Air pollutants
    - GRIMM (PM$_{10}$, PM$_{2.5}$, PM$_{1}$)
    - P-trak (UFP: 0.02-1! m)
Exposure Measurement Instruments

- Grimm particle monitor (PM10, PM2.5, PM1)
- P-trak (ultrafine particles, 0.02-1 µm)
- GPS and PowerTap
2 cycling routes:

Downtown
Geometric mean
UFP= 16,226 pt/cc

Residential
Geometric mean
UFP= 10,047 pt/cc

P= < 0.001
Health Impact Measurements

- EndoPAT- blood vessel function
  - To detect endothelial dysfunction
- Spirometry
  - Lung function
- Blood test
  - Serum extracted from blood sample and frozen for analysis later (C-reactive protein, IL-6, 8-OHdG)

Measured before and after each trial
Measuring minute ventilation ($V_E$) to determine relationship with Power Output and Heart Rate

- PowerTap hub measures power output (in watts) while riding
- Minute ventilation measured using respirometer & Velotron:

\[ V_E = \text{breaths/\text{min}} \times V_{\text{Tidal}} \]

\[ V_E \times \text{ride time} = \text{total air breathed during trial} \]
Stepwise measure of minute ventilation

Breathing and Heart Rate During Exercise Test

\[ y = 0.7593x - 46.749 \]

\[ R'' = 0.96561 \]

- min vent
- Linear(min vent)
Results
### Ride Results: Measured Air Particulate Concentrations Along Bicycle Routes

<table>
<thead>
<tr>
<th>Variable</th>
<th>Downtown Route</th>
<th>Residential Route</th>
<th>Mean Downtown - Mean Residential</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Geo. Mean</td>
<td>Geo. Mean</td>
<td>Mean Difference [95%CI]</td>
</tr>
<tr>
<td><strong>Ultrafine Particles</strong> (pt/cc)</td>
<td>16226</td>
<td>10047</td>
<td>5495 (2918, 8072)</td>
</tr>
<tr>
<td>PM10 µg/m³</td>
<td>11</td>
<td>8.4</td>
<td>2.5 (-0.70, 5.6)</td>
</tr>
<tr>
<td>PM2.5 µg/m³</td>
<td>6.0</td>
<td>4.7</td>
<td>1.1 (-1.2, 3.4)</td>
</tr>
<tr>
<td>PM1 µg/m³</td>
<td>3.8</td>
<td>2.9</td>
<td>0.91 (-0.87, 2.7)</td>
</tr>
</tbody>
</table>

* 2 outliers removed (fire conditions & equip. malfunction)
Ventilation Ratio During Ride: At Rest

Average L/min breathed during bike ride vs. L/min of air breathed while sitting on bike

Overall ratio of 21 subjects (2011 group)

Average = 2.8

Males: 2.9 (s.d. = 2.4)

Females: 2.7 (s.d. = 1.3)

Other research:

Int Panis et al. (2010): 4.3
Zuurbier et al. (2009): 2.1
O’Donoghue et al. (2007): 2.6
Van Wijnen et al. (1995): 2.3
Estimated intake of UFP

- $V_E \times \text{ride time} = \text{total air breathed during trial}$
- Estimated intake = $V_E \times \text{ride time} \times \text{air pollutant concentration (UFP)}$

Estimated intake riding = 28.1 billion UFP particles

(@ rest = 9.5 billion)
# Health Results (Paired T-tests)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Downtown Route</th>
<th>Residential Route</th>
<th>Δ Downtown - Δ Residential</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Change (Post-Pre) Mean [sd]</td>
<td>Change (Post-Pre) Mean [sd]</td>
<td>Mean Difference [95%CI]</td>
</tr>
<tr>
<td><strong>Endothelial Function</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EndoPAT (RHI)</td>
<td>-0.18 [0.86]</td>
<td>0.25 [0.63]</td>
<td>-0.38 [-0.75, -0.02]</td>
</tr>
<tr>
<td><strong>Spirometry (Lung Function)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FVC (L)</td>
<td>0.08 [0.15]</td>
<td>0.01 [0.31]</td>
<td>0.03 [-0.08, 0.13]</td>
</tr>
<tr>
<td>FEV1 (L)</td>
<td>0.05 [0.12]</td>
<td>0.05 [0.17]</td>
<td>0.00 [-0.06, 0.06]</td>
</tr>
<tr>
<td>FEV1/FVC (%)</td>
<td>0.00 [0.02]</td>
<td>0.01 [0.04]</td>
<td>-0.00 [-0.02, 0.01]</td>
</tr>
<tr>
<td>FEF25-75 (L/s)</td>
<td>0.11 [0.25]</td>
<td>0.09 [0.42]</td>
<td>0.02 [-0.13, 0.17]</td>
</tr>
<tr>
<td><strong>Blood Measures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRP (mg/L)</td>
<td>0.01 [0.06]</td>
<td>0.01 [0.11]</td>
<td>0.00 [-0.04, 0.05]</td>
</tr>
<tr>
<td>IL-6 (pg/ml)</td>
<td>0.55 [3.30]</td>
<td>-0.45 [3.54]</td>
<td>0.95 [-0.98, 2.89]</td>
</tr>
<tr>
<td>8-OHdG (ng/ml)</td>
<td>0.00 [0.11]</td>
<td>-0.03 [0.11]</td>
<td>0.02 [-0.03, 0.07]</td>
</tr>
</tbody>
</table>
Models are a way of combining group data to predict HOW multiple variables are affected.

Mixed effects models, $PM_x$ geom. means:

1) Health response = $\beta_{Route} + subject$

2) “ = $\beta_{Pollutant} + subject$

3) “ = $\beta_{Pollutant} + \beta_{Route} + subject$

Ex. Post-Pre RHI = $\beta_{PM2.5} + \beta_{Route (Dt. or Res.)} + subject$

(endothelial function)

No significant results for 2) or 3)
**Health Variable** = $\beta_{\text{Route (D.t. or Res') + subject}}$

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\beta_{\text{Route (+ subj)}}$</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>*RHI “post” - “pre”</td>
<td>-0.43</td>
<td>-0.78, -0.077</td>
</tr>
<tr>
<td>FEV₁ in mL/s “post” - “pre”</td>
<td>0.72</td>
<td>-59, 61</td>
</tr>
<tr>
<td>FEV₁/FVC “post” - “pre”</td>
<td>-0.0035</td>
<td>-0.015, 0.0084</td>
</tr>
<tr>
<td>FVC in mL “post” - “pre”</td>
<td>26</td>
<td>-75, 130</td>
</tr>
<tr>
<td>CRP in mg/dL “post” - “pre”</td>
<td>0.0022</td>
<td>-0.038, 0.043</td>
</tr>
<tr>
<td>IL-6 in pg/mL “post” - “pre”</td>
<td>0.99</td>
<td>-0.60, 2.6</td>
</tr>
<tr>
<td>8-OHdG in pg/mL “post” - “pre”</td>
<td>28</td>
<td>-20, 76</td>
</tr>
</tbody>
</table>

-> only the $\beta$ value for RHI is statistically significant
Study Limitations

- Short time for response (1hr)
  - ex. repeating tests 6 hours later may show more change
  - Acute effects only- not how long effects last? long term effects?

- Negative impacts on blood vessel function
  - may not be due to air pollution difference alone
    - other things make up the route (noise, stress, more hills?, some combination together?)
Riding along a higher traffic route may affect blood vessel (endothelial) function and inflammation compared to riding a lower traffic route.

Evidence that health gains (from exercise) to population are greater than risks from air pollution is valuable to decrease risk further (Rojas-Rueda et al. 2011).

People should not have to choose between cycling and breathing clean air!
Committee:

›! Dr. Michael Brauer (supervisor)
›! Dr. Christopher Carlsten
›! Dr. Michael Koehle

›! Assistants: Catherine Steer, Alistair Scott, Angie White, Luisa Giles, Meaghan McNutt, Tracy Kirkham, Barb Karlen, Sébastien Brideau, and other APEL staff

›! Subjects!!!

›! Funding from Health Canada
References

Title slide photo from City of Vancouver-
http://vancouver.ca/engsvcs/transport/cycling/plans/network.htm

1- Statistics Canada/Public Health Agency of Canada (2007-2009)
http://www.statcan.gc.ca/daily-quotidien/100113/dq100113a-eng.htm

2- Public Health Agency of Canada (2002)

Slide 4&5 photo- Picture from
http://international.iteem.ec-lille.fr/europe/periodical-technical-inspection-of-the-future/

Burrard Bridge photo-
http://www.granvilleonline.ca/gr/blogs/editors/2010/07/14/burrard-bridge-bike-lane-here-stay

Cypress route photo-
http://vancouver.ca/engsvcs/transport/cycling/bikeways/routes/cypress.htm
Stepwise power test using Velotron (2011)

- $V_E$ at rest
- 20/30 watts for 2 minutes (Female/Male), increasing by 20/30 watts every 2 minutes
- 30-second minute ventilation measurements taken over the second minute to create VE-HR-watts relationship

<table>
<thead>
<tr>
<th>Ex.</th>
<th>Watts</th>
<th>HR</th>
<th>VE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (rest)</td>
<td>0</td>
<td>80</td>
<td>8L/min</td>
</tr>
<tr>
<td>20</td>
<td>84</td>
<td></td>
<td>12L/min</td>
</tr>
<tr>
<td>40</td>
<td>90</td>
<td></td>
<td>18L/min</td>
</tr>
<tr>
<td>60</td>
<td>95</td>
<td></td>
<td>23L/min</td>
</tr>
</tbody>
</table>
Estimating dose of UFP

\[ V_E \times \text{ride time} = \text{total air breathed during trial} \]
\[ \text{Est'd dose} = V_E \times \text{ride time} \times \text{air pollutant concentration (UFP)} \]

At rest:
\[ V_E (11.3 \text{ L/min}) \times \text{time (66.08mins)} \times \text{geo. Mean of UFP (12785pt/cc} \times 1000\text{cc/L)} \]

During ride:
\[ V_E (33.3 \text{ L/min}) \times \text{time (66.08mins)} \times \text{geo. Mean of UFP (12785pt/cc} \times 1000\text{cc/L)} \]

Est’d dose @rest = 9 546 610 640 UFP particles
Est’d dose riding = 28 132 932 240 UFP particles

Almost 2.95 times the number of particles from riding: rest