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

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Cycling is good for us!

- Benefits of active transportation:
  - May help reduce excess weight
    - Canadian adults: 37% overweight, 24% obese[1]
  - Decreased stress and injury susceptibility
  - Chronic disease prevention (cancer, type 2 diabetes, CHD)

- Cycling decreases:
  - traffic congestion
  - air pollution & GHG emissions

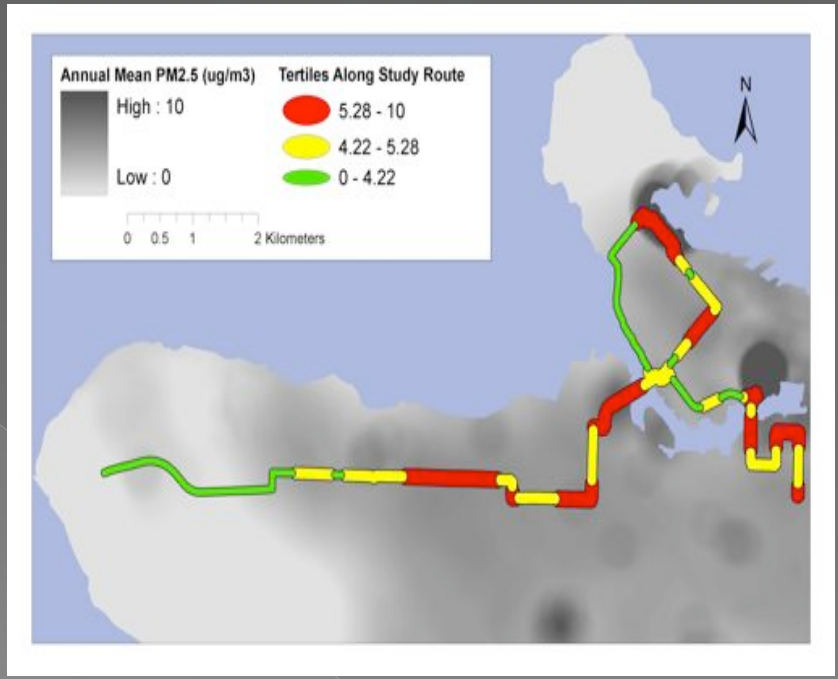
[1]Canadian Health Measures Survey (2007-2009)

Higher cyclist exposure on high traffic routes

Other research:

Air pollution measured in Vancouver[1]

- Airborne particle levels varied according to:
  - proximity to major roadways
  - heavy traffic volumes



The Netherlands[2]

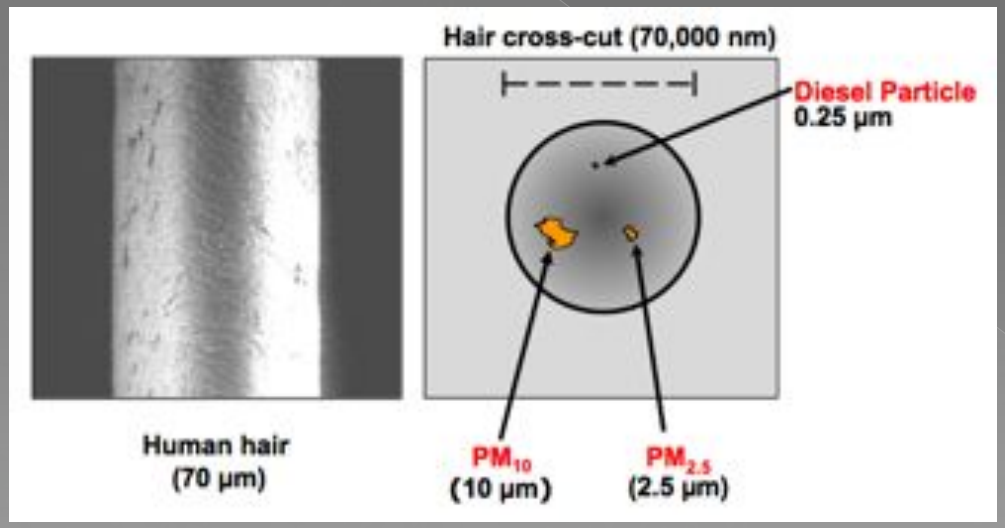
- 59% higher ultrafine particle levels on high-traffic vs. low-traffic routes

[1]Thai et al. 2007; [2]Strak et al. 2010

What air pollutants?

- Many exist- gases such as benzene, SO_2, NO_X; particles of different sizes
  - Major sources include road traffic (fossil fuel combustion), but also industry, natural sources

Ex. PM_{10} are particles ! 10μm in aerodynamic diameter



Particulate Matter Deposition

*PM_{10} = 10 000 nm

Areas of attack	Particle size
Nose and throat area	5,000 – 10,000 nm
Windpipe	3,000 – 5,000 nm
Bronchia	2,000 – 3,000 nm
Bronchial	1,000 – 2,000 nm
Alveoli (UFP range)	100 – 1,000 nm

We measured particulate matter– "PM", in a number of size ranges ($PM_{10,}$ $PM_{2.5,}$ $PM_{1,}$ UFP- $PM_{0.02-1}$)

How much more (pollution) do cyclists inhale?

- Cyclists have breathing rates 2 – 4 x higher than those of car passengers[1,2]"
- Cyclists are close to the pollution source"

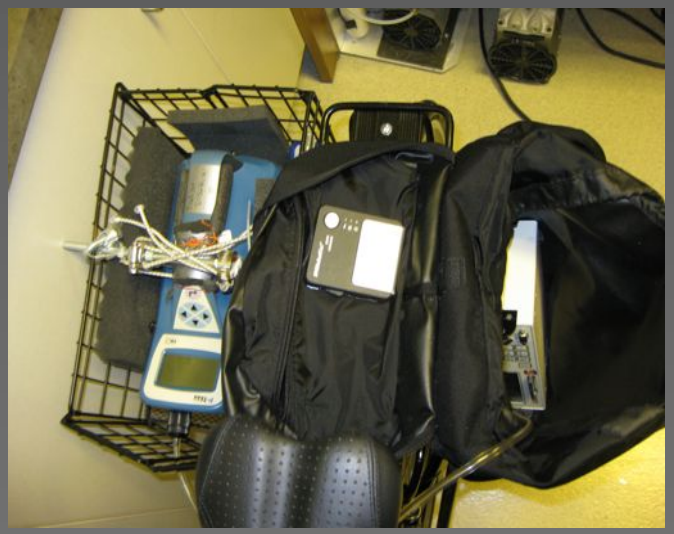
Pollution exposure X Breathing = Intake

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:

<u>Downtown</u>
Geometric mean
UFP= 16 226 pt/cc

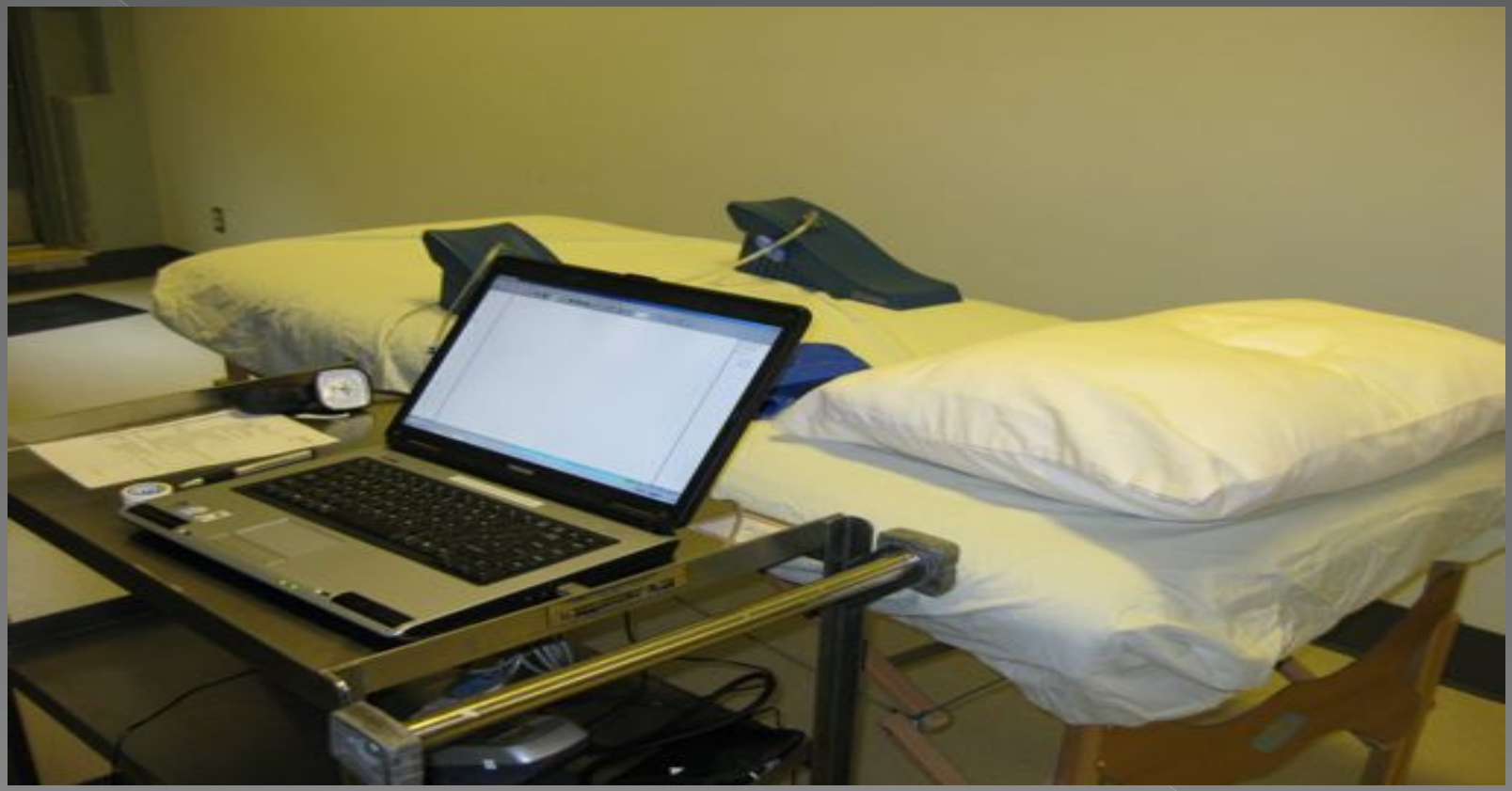
<u>Residential</u>
Geometric mean
UFP= 10 047 pt/cc

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




SensiCare
SensiCare

Measuring minute ventilation (V_E) to determine relationship with Power Output and Heart Rate

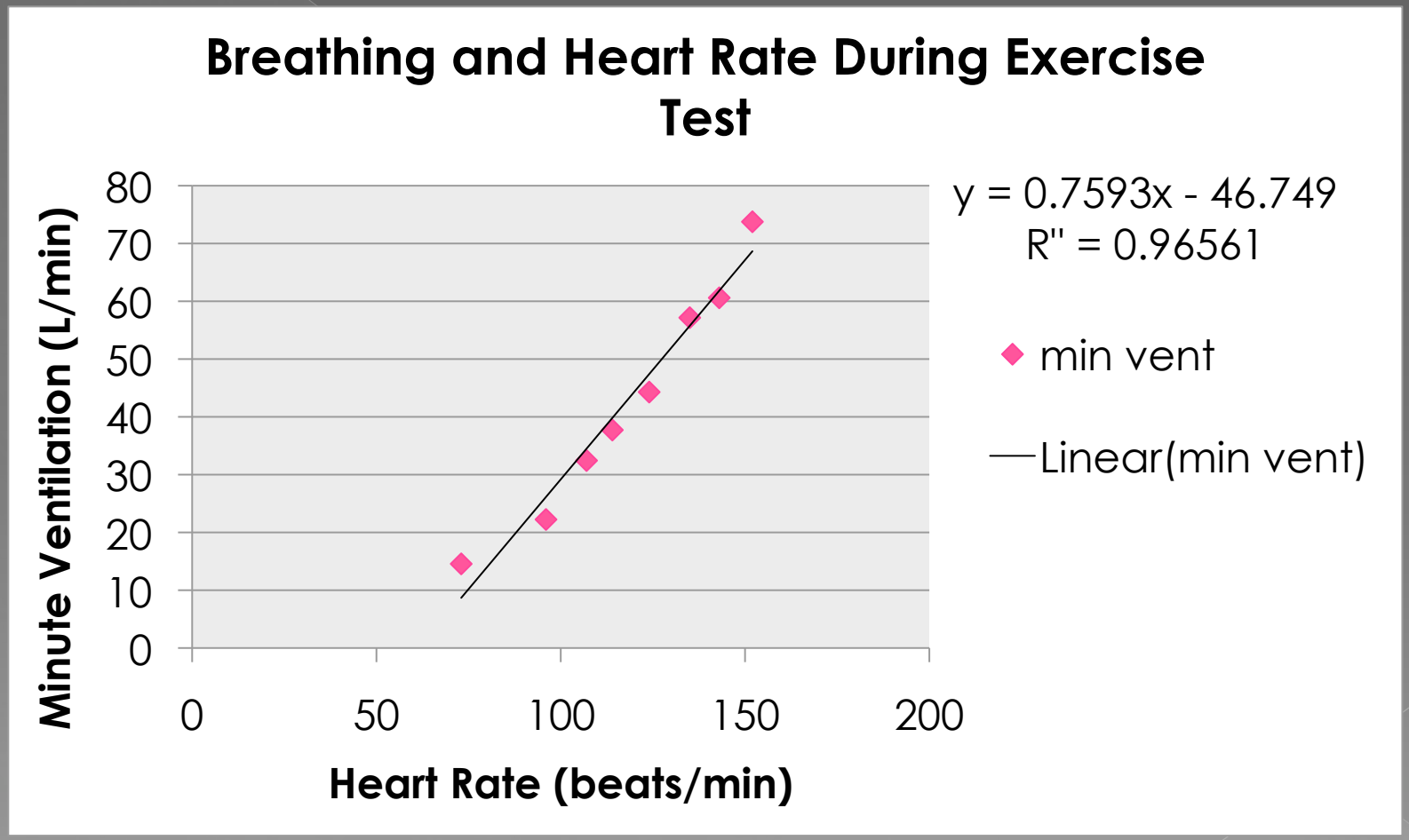
- PowerTap hub measures power output (in watts) while riding
- Minute ventilation measured using respirometer & Velotron:

V_E = breaths/min x V_{Tidal}

V_E x ride time = total air breathed during trial

Methods

Stepwise measure of minute ventilation



Results

Ride Results: Measured Air Particulate Concentrations Along Bicycle Routes

Variable	Downtown Route	Residential Route	Mean Downtown - Mean Residential	
	Geo. Mean	Geo. Mean	Mean Difference [95%CI]	Paired T-test P-value
Ultrafine Particles (pt/cc)	16226	10047	5495 (2918, 8072)	0.00013
PM10 $\mu g/m^3$	11	8.4	2.5 (-0.70, 5.6)	0.12
PM2.5 $\mu g/m^3$	6.0	4.7	1.1 (-1.2, 3.4)	0.32
PM1 $\mu g/m^3$	3.8	2.9	0.91 (-0.87, 2.7)	0.31

* 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 * ride time = total air breathed during trial
- Estimated intake = V_E * ride time * air pollutant concentration (UFP)

Estimated intake riding = 28.1 billion UFP particles

(@ rest = 9.5 billion)

Health Results (Paired T-tests)

Variable	Downtown Route	Residential Route	Δ Downtown - Δ Residential	
	Change (Post-Pre) Mean [sd]	Change (Post-Pre) Mean [sd]	Mean Difference [95%CI]	Paired T-test P-value
Endothelial Function				
EndoPAT (RHI)	-0.18 [0.86]	0.25 [0.63]	-0.38 [-0.75, -0.02]	0.04*
Spirometry (Lung Function)				
FVC (L)	0.08 [0.15]	0.01 [0.31]	0.03 [-0.08, 0.13]	0.59
FEV1 (L)	0.05 [0.12]	0.05 [0.17]	0.00 [-0.06, 0.06]	0.98
FEV1/FVC (%)	0.00 [0.02]	0.01 [0.04]	-0.00 [-0.02, 0.01]	0.63
FEF_{25-75} (L/s)	0.11 [0.25]	0.09 [0.42]	0.02 [-0.13, 0.17]	0.76
Blood Measures				
CRP (mg/L)	0.01 [0.06]	0.01 [0.11]	0.00 [-0.04, 0.05]	0.92
IL-6 (pg/ml)	0.55 [3.30]	-0.45 [3.54]	0.95 [-0.98, 2.89]	0.32
8-OHdG (ng/ml)	0.00 [0.11]	-0.03 [0.11]	0.02 [-0.03, 0.07]	0.37

Health Results Beyond the paired t-tests -> Mixed Models

- 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 = β_{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 = $ß_{Route\ (D.t.\ or\ Res'l)}$ + subject

Variable	$ß_{Route\ (+\ subj)}$	95% CI
*RHI "post" - "pre"	-0.43	-0.78, -0.077
FEV_1 in mL/s "post" - "pre"	0.72	-59, 61
FEV_1/FVC "post" - "pre"	-0.0035	-0.015, 0.0084
FVC in mL "post" - "pre"	26	-75, 130
CRP in mg/dL "post" - "pre"	0.0022	-0.038, 0.043
IL-6 in pg/mL "post" - "pre"	0.99	-0.60, 2.6
8-OHdG in pg/mL "post" - "pre"	28	-20, 76

-> only the ß 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?)

What do these results mean?

- Riding along a higher traffic route may
  - 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

  valuable to decrease risk further

  (Rojas-Rueda et al. 2011)

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

Thank You

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References

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Slide 4&5 photo- Picture from
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Burrard Bridge photo-
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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

Ex. Watts	HR	VE
0 (rest)	80	8L/min
20	84	12L/min
40	90	18L/min
60	95	23L/min

Estimating dose of UFP

- V_E * ride time = total air breathed during trial
- Est'd dose= V_E * ride time * air pollutant concentration (UFP)

At rest:

V_E (11.3 L/min) * time (66.08mins) * geo. Mean of UFP (12785pt/cc x 1000cc/L)

During ride:

V_E (33.3 L/min) * time (66.08mins) * geo. Mean of UFP (12785pt/cc x 1000cc/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