

Air Filter and Stove Exchange Impacts on Indoor Air Quality and Health

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Stove Exchange Programs

Bulkley Valley & Lakes District (BVLD), BC

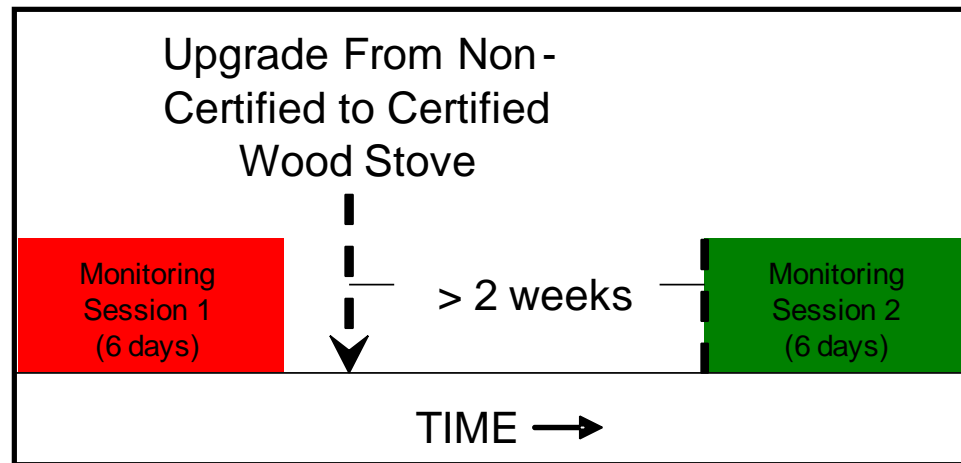
- **BVLD Airshed**
 - Wood is primary fuel in $\frac{2}{3}$ of homes
 - 60% are non-EPA certified
 - >4,000 non-certified stoves in the airshed
- **Incentives**
 - \$250 from airshed mgmt society
 - Retailer discounts ~10%
- **Education & Advertising**
 - Burn-it-smart workshops
 - Radio & print ads
- **By-laws**
 - Required removal of non-certified appliances Burns Lake, Houston, & Smithers



Woodstove Exchange Study (WESt)

Winter 2007 – 2008

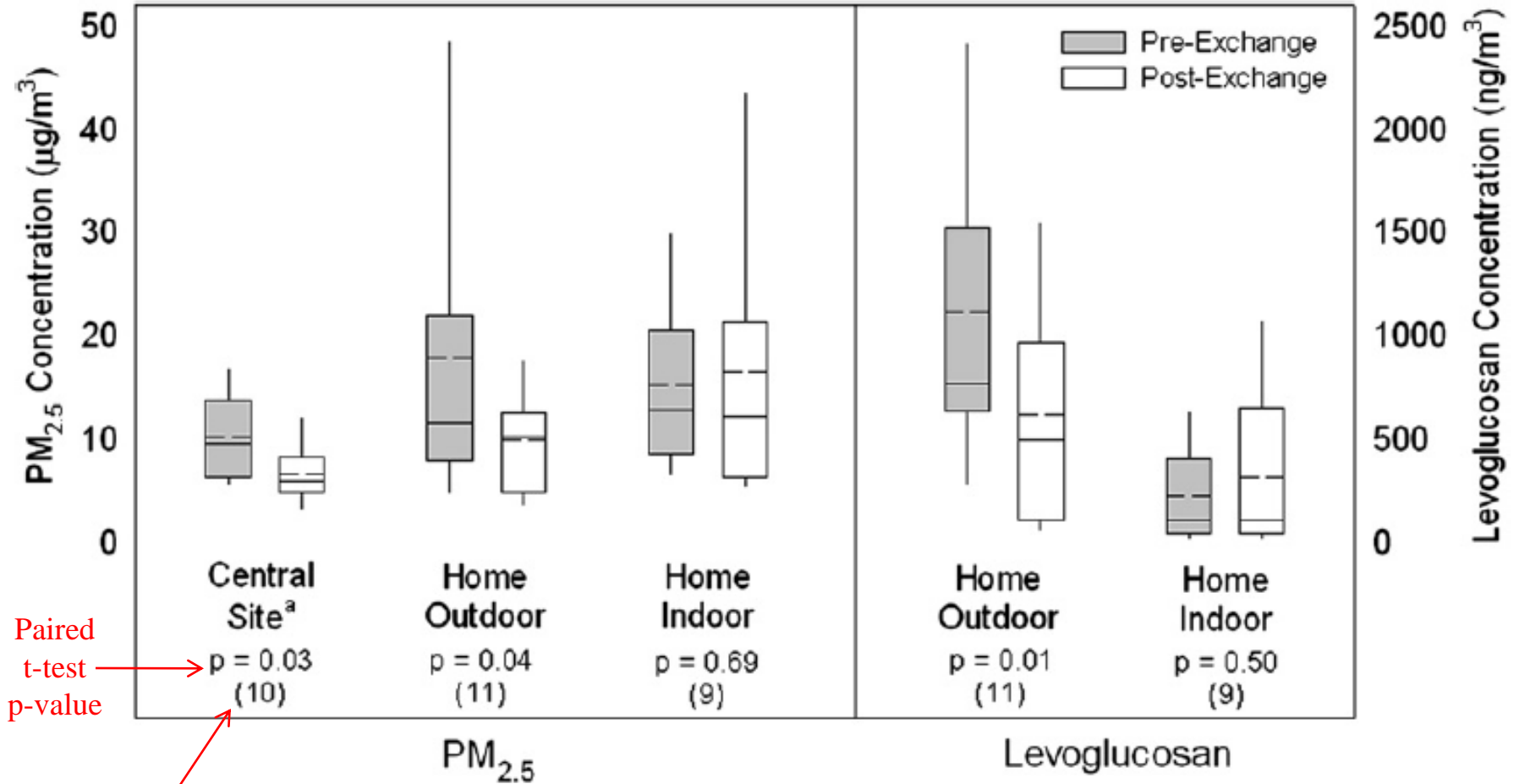
- Goal: determine the impact of stove technology upgrades on *indoor* pollution levels in homes undergoing exchange
- 15 homes in Smithers & Telkwa
 - Non-certified woodstove as 1⁰ or 2⁰ heat source
 - 6 days of monitoring, indoors & out, pre- and post-exchange
 - Diary of stove use, activities



Woodstove Exchange Study (WESt)

Winter 2007 – 2008

NO CONSISTENT CHANGES IN INDOOR CONCENTRATIONS AFTER STOVE EXCHANGE



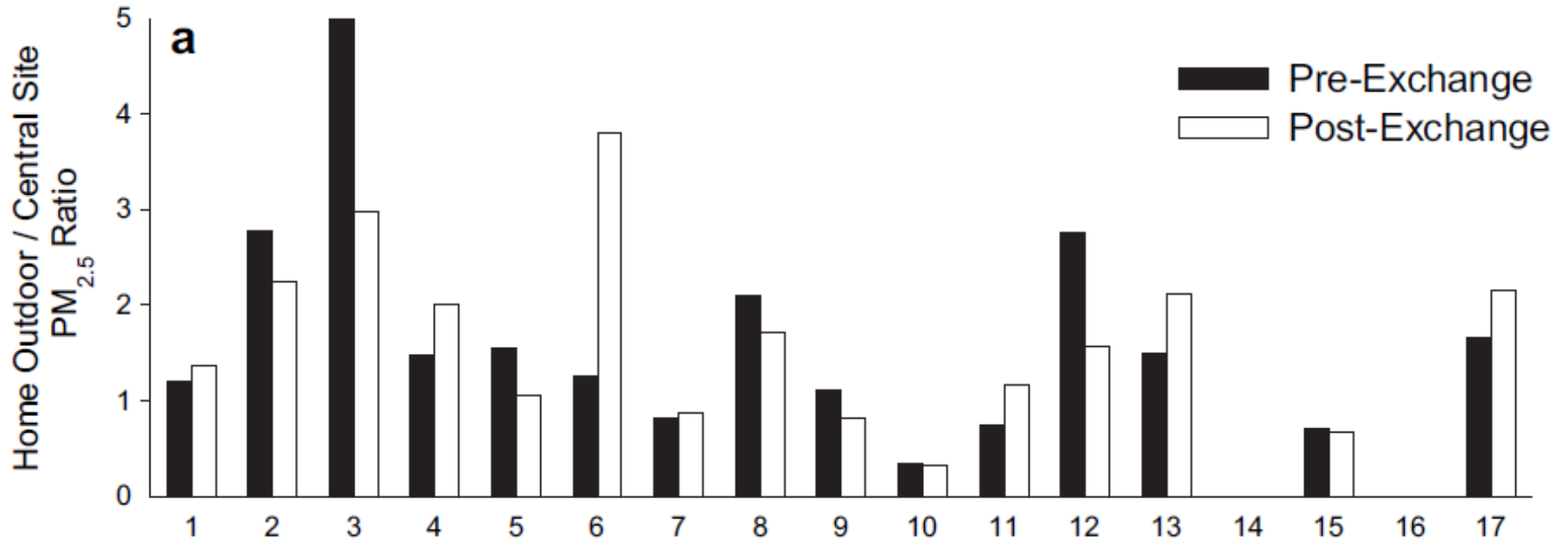
Paired t-test p-value

of homes with a decrease after stove exchange

Woodstove Exchange Study (WEST)

Winter 2007 – 2008

**NO CONSISTENT CHANGES IN OUTDOOR CONCENTRATIONS
AFTER ADJUSTING FOR AIRSHED-WIDE TEMPORAL CHANGES**



Woodstove Exchange Study (WEST)

Winter 2007 – 2008

- Low infiltration (cold climate; tightly sealed homes)
- Indoor sources contribute $\frac{2}{3}$ of the indoor PM_{2.5}

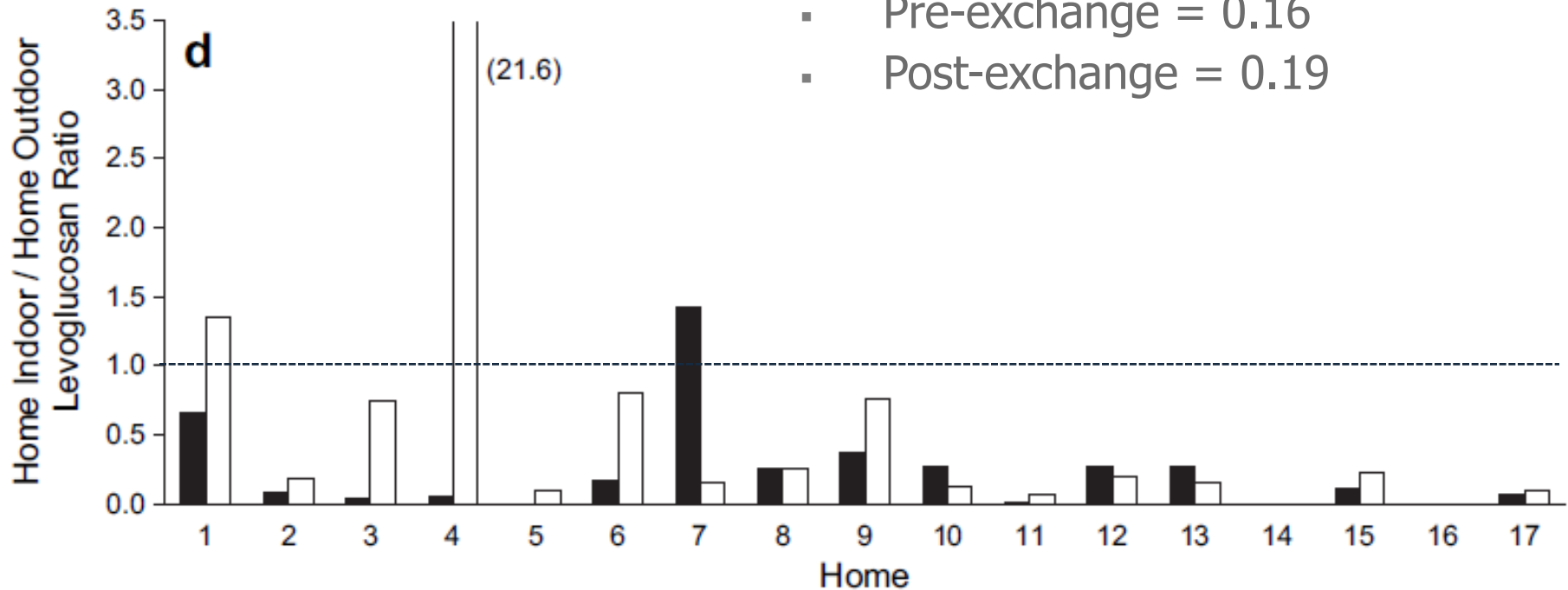
	Pre-Exchange	Post-Exchange
Indoor PM _{2.5}	13.7 ± 6.3 µg/m ³	13.2 ± 6.9 µg/m ³
Infiltration Efficiency	0.32 ± 0.17	0.33 ± 0.11
Indoor Source Contribution to Indoor PM _{2.5} Concentration	65 ± 23 %	68 ± 27 %

Woodstove Exchange Study (WESt)

Winter 2007 – 2008

WOODSMOKE IS NOT A SIGNIFICANT *INDOOR* SOURCE OF PM_{2.5} IN MOST HOMES

- Median levoglucosan I/O ratios
 - Pre-exchange = 0.16
 - Post-exchange = 0.19



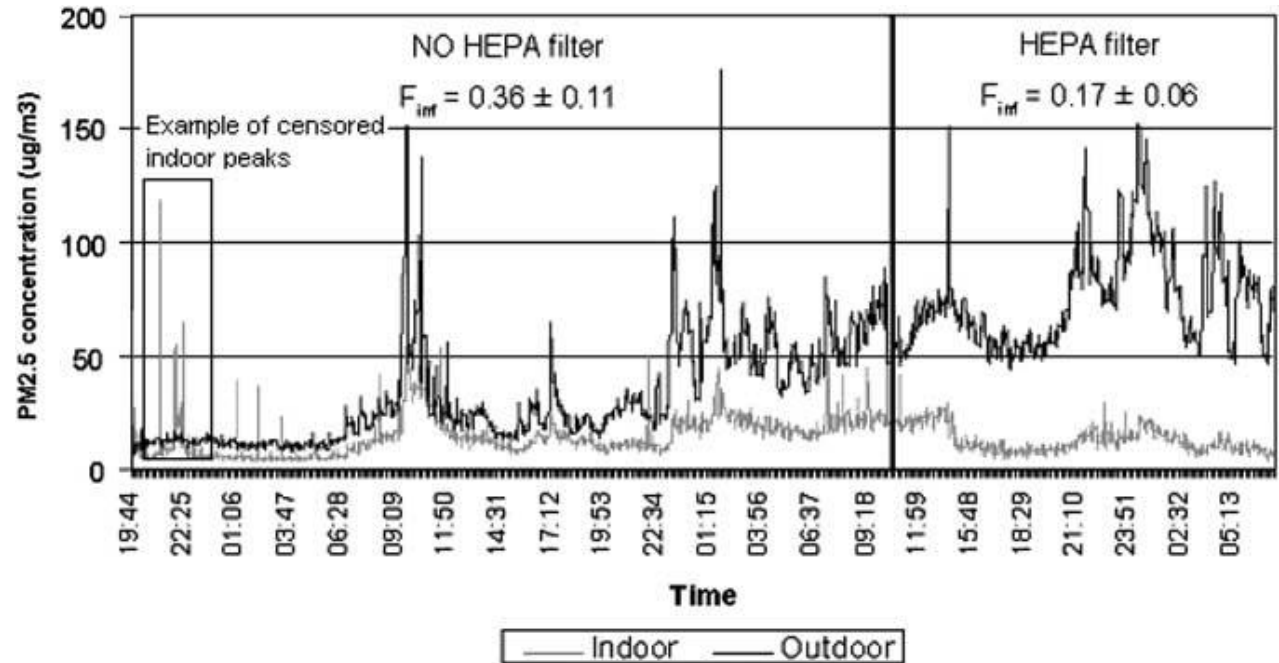
Woodstove Exchange Study (WESt)

Winter 2007 – 2008

- Summary
 - Unlike in Libby, no consistent effect of stove exchange on *indoor* levels
 - Outdoor concentrations were lower after stove exchange, but change was driven by airshed-wide changes (meteorology)
 - Low infiltration
 - Indoor sources contribute the majority of indoor $PM_{2.5}$
 - Correlations & I/O ratios suggest woodsmoke not a major *indoor* $PM_{2.5}$ source in most of these wood-burning homes

High Efficiency Particulate Air (HEPA) Filters

- Appropriately-sized HEPA filters reduce indoor PM_{2.5} concentrations by $\geq 50\%$

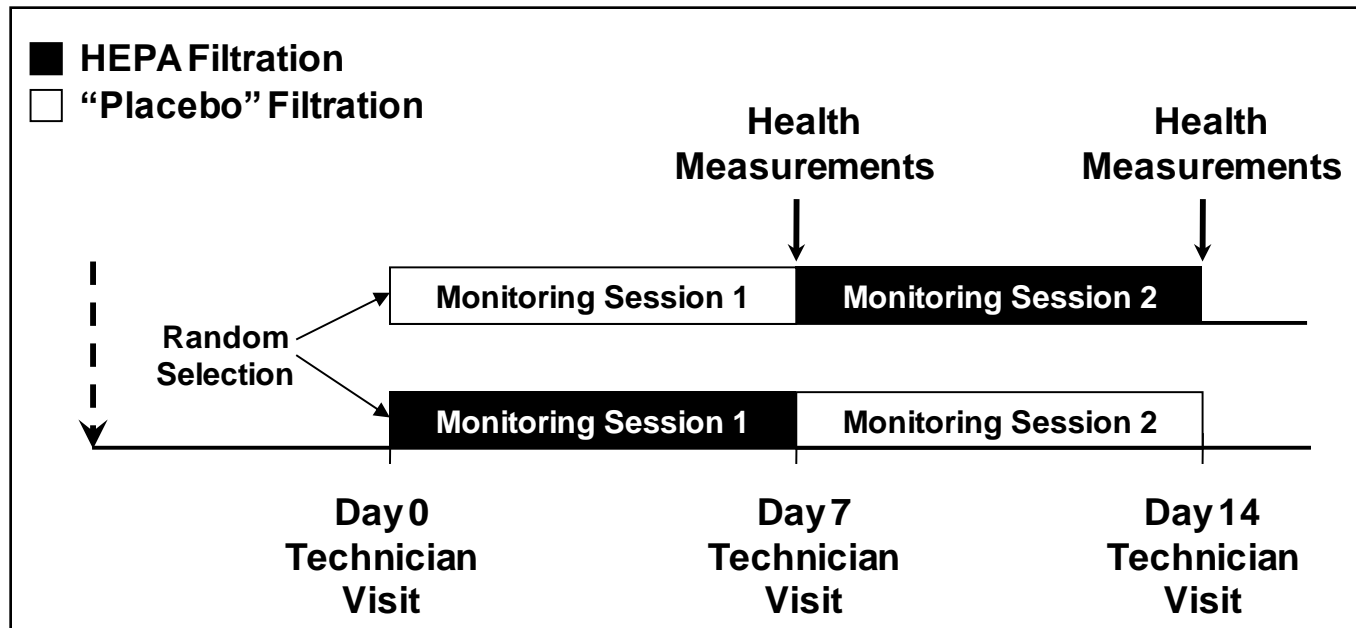


- Most health research focused on allergens and asthma symptoms (see, for example, Sublett et al., 2010)
- Limited evidence for other health endpoints

Woodstove Exchange Study (WESt)

Winter 2008 – 2009

- Goal: Evaluate the impact of HEPA filters on pre-clinical markers of cardiovascular risk among healthy adults in a woodsmoke-dominated airshed
 - Excluded smoking households
 - Prioritized 'healthy' adults, multiple participants in a home



Woodstove Exchange Study (WESt)

Winter 2008 – 2009

- Health Measurements
 - Reactive hyperemia index (RHI) measured as an indicator of microvascular **endothelial function**
 - Markers of **systemic inflammation**
 - Serum C-reactive protein (CRP) and interleukin-6 (IL-6)
 - Manual counts of band cells
 - Markers of **oxidative stress**
 - Malondialdehyde (MDA)
 - 8-iso-prostaglandin F2 α (“8-isoprostane”)
- Exposure Assessment
 - 7-day PM_{2.5} filter samples indoors & outdoors
 - Analyzed for woodsmoke tracer levoglucosan
 - Participants completed hourly time-location-activity diaries

Woodstove Exchange Study (WESt)

Winter 2008 – 2009

CHARACTERISTICS OF 45 STUDY PARTICIPANTS

Variable	Mean \pm SD or Number (%)
Age (years)	43.0 \pm 9.9
BMI (kg/m ²)	25.7 \pm 3.5
Female	24 (53%)
Asthma	2 (4%)
Hypertension	1 (2%)
Diabetes	0 (0%)
Employed Outside Home	40 (89%)
Wood Stove Used in Home	23 (51%)

Woodstove Exchange Study (WESt)

Winter 2008 – 2009

POLLUTION MEASUREMENTS IN 25 HOMES

Variable	HEPA Off		HEPA On		Paired t-test p-value
	Mean ± SD	Median	Mean ± SD	Median	
7-day Avg. Indoor Temperature ($^{\circ}\text{C}$) ^a	19.7 ± 1.4	19.4	19.8 ± 1.7	19.4	0.75
7-day Avg. Indoor Relative Humidity (%) [*]	35.1 ± 3.3	36.0	35.3 ± 3.4	33.7	0.90
PM _{2.5} Outdoors ($\mu\text{g}/\text{m}^3$)	10.8 ± 5.0	9.0	9.8 ± 4.2	8.9	0.26
PM _{2.5} Infiltration Efficiency (unitless)	0.34 ± 0.17	0.30	0.20 ± 0.17	0.13	<0.01
PM _{2.5} Indoors ($\mu\text{g}/\text{m}^3$)	11.2 ± 6.1	10.5	4.6 ± 2.6	3.9	<0.01
PM _{2.5} Outdoor-Generated ($\mu\text{g}/\text{m}^3$)	3.5 ± 2.3	3.6	1.5 ± 0.9	1.4	<0.01
PM _{2.5} Indoor-Generated ($\mu\text{g}/\text{m}^3$)	7.6 ± 6.6	6.3	3.0 ± 2.8	2.1	<0.01
Levoglucosan Outdoors (ng/m^3) ^a	613 ± 548	415	530 ± 358	471	0.18
Levoglucosan Indoors (ng/m^3)	127 ± 191	73	33 ± 39	19	0.01
Levoglucosan / PM _{2.5} Outdoors (%) [†]	5.1 ± 2.8	5.3	5.3 ± 1.8	5.1	0.79
Levoglucosan / PM _{2.5} Indoors (%)	1.0 ± 1.1	0.7	0.9 ± 1.3	0.7	0.61

Woodstove Exchange Study (WESt)

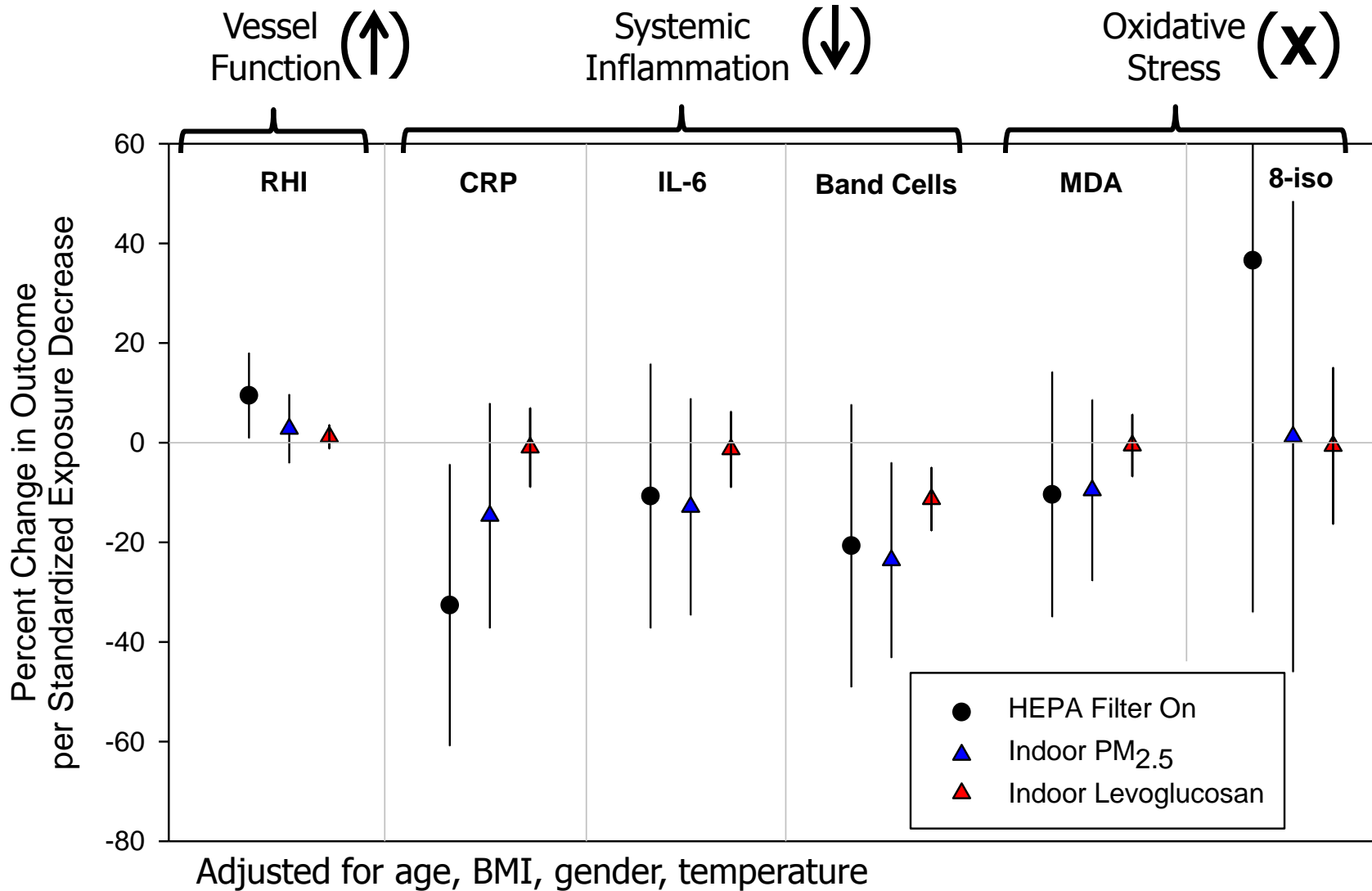
Winter 2008 – 2009

SUMMARY STATISTICS BY HEPA STATUS

Variable	HEPA Off		HEPA On		Paired t-test p-value
	Mean \pm SD	Median	Mean \pm SD	Median	
Room Temperature During RHI Measurement ($^{\circ}$ C)	19.3 \pm 1.4	19	19.1 \pm 1.0	19	0.44
% of Time Indoors at Home	77.0 \pm 13.2	78.4	76.0 \pm 12.8	75.0	0.45
% of Time at Work	14.8 \pm 11.7	16.0	16.3 \pm 11.9	17.4	0.29
% of Time in Transit	5.0 \pm 5.5	3.1	5.4 \pm 5.6	3.1	0.49
% of Hours with ETS Exposure Reported	0.1 \pm 0.4	0.0	0.1 \pm 0.6	0.0	0.76
% of Hours Cooking	7.2 \pm 5.1	6.8	7.8 \pm 4.9	8.8	0.35
Systolic Blood Pressure (mmHg)*	112.4 \pm 10.8	113	112.2 \pm 11.5	112	0.88
Diastolic Blood Pressure (mmHg)*	68.6 \pm 7.6	68	68.4 \pm 8.2	67	0.80
Reactive Hyperemia Index	2.06 \pm 0.63	1.93	2.28 \pm 0.72	2.32	0.03
C-reactive Protein (mg/L)	1.00 \pm 0.78	0.83	0.78 \pm 0.74	0.48	0.06
IL-6 (pg/mL)	6.11 \pm 19.34	1.66	4.12 \pm 8.73	1.18	0.26
Band Cells (% of PMN) [†]	4.62 \pm 3.49	4.00	3.57 \pm 2.84	3.00	0.08
Malondialdehyde (μ M)	2.64 \pm 1.78	2.14	2.61 \pm 3.34	1.83	0.94
8-isoprostane (pg/mL) [‡]	8.78 \pm 12.29	3.57	10.90 \pm 14.32	4.58	0.48

Woodstove Exchange Study (WEST)

Winter 2008 – 2009



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- Summary
 - Portable HEPA filters reduced average indoor PM_{2.5} concentrations by 60%
 - Evidence of HEPA-induced improvements in endothelial function and decreases in systemic inflammatory markers
 - Benefits in spite of modest baseline exposures and relatively young, healthy population
 - Some evidence of stronger relationships among participants residing in wood-burning homes
 - No evidence of effects on oxidative stress

Policy Implications

- Evidence does *not* support stove technology upgrades for reducing *indoor* concentrations in homes with woodstoves
 - Differs from Libby, perhaps due to stove installation and/or operator
 - Effects on community-level outdoor concentrations have not yet been evaluated
- Evidence of HEPA filter benefits for indoor exposure and “pre-clinical” CV risk markers
 - Limited ‘downside’ to portable HEPA filters (noise, cost)
 - Improve air quality where most time is spent
 - Must be appropriately sized for room volume
 - No research on long-term CV benefits of HEPA filtration (e.g. reduction in risk of MI, stroke, etc.)

Collaborators

- Michael Brauer*
- Chris Carlsten
- Barb Karlen
- Sara Leckie
- Gail Millar (UNBC)
- Stephan van Eeden
- Sverre Vedal (UW)
- Imelda Wong

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 - Cris Barzan

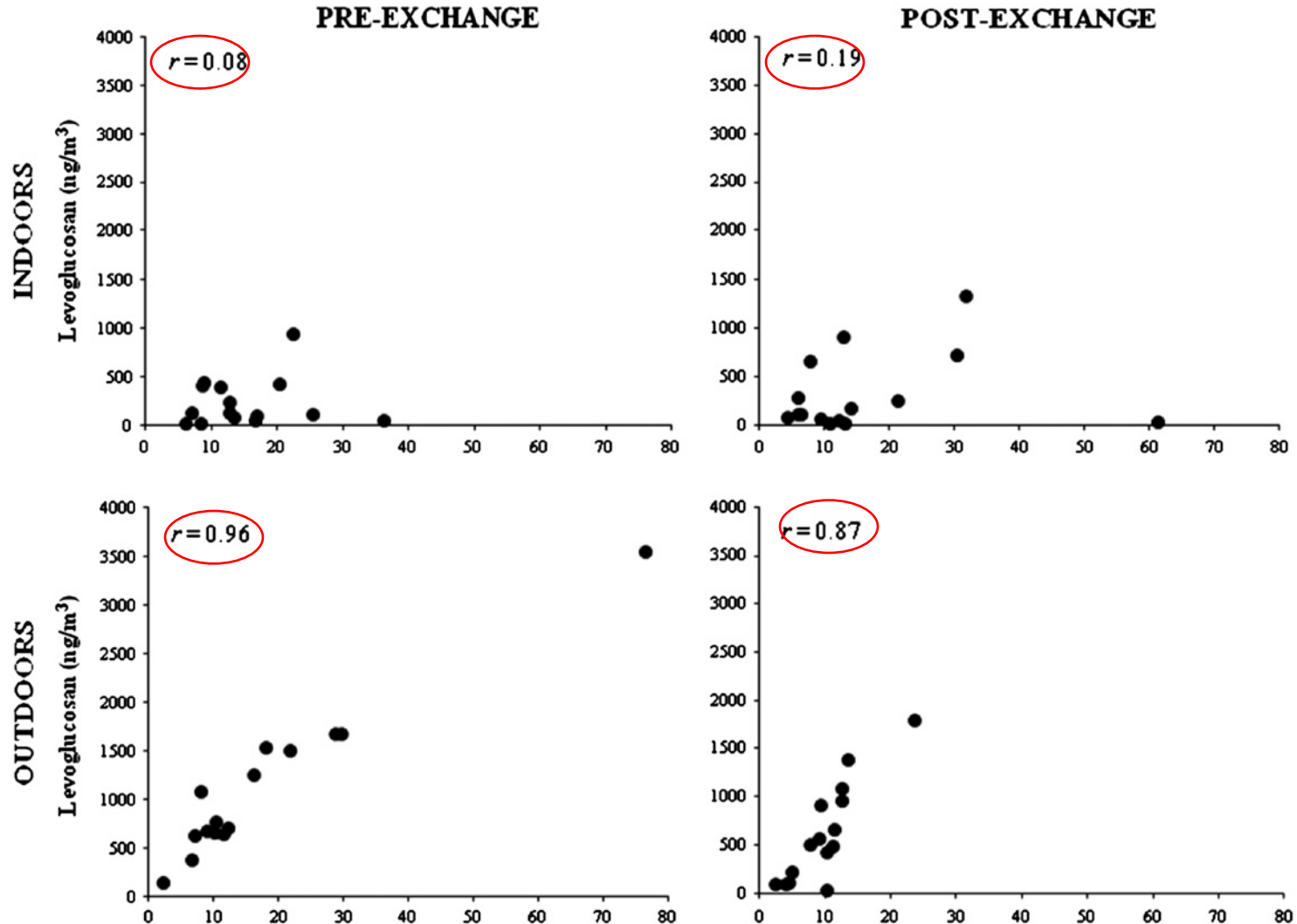
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EXPLORATION OF EFFECT MODIFICATION BY USE OF WOOD-BURNING STOVE

