

Particulate Matter Reproducibility and Air Pollution Epidemiology

Richard T. Burnett, Ph.D.
Health Canada

Health Effects Institute 2018 Annual
Conference, Chicago, USA

Lave, L. B., and Seskin, E. P. Air Pollution and Human Health. Johns Hopkins University Press, Baltimore, 1977.

**Air Pollution and Human Health:
A Review and Reanalysis**

**by L. A. Thibodeau,* R. B. Reed,* Yvonne M. M. Bishop,*
and L. A. Kammerman***

Since 1970, Lave and Seskin have published a series of articles dealing with the question, "Does air pollution shorten lives?" Their recent book reports revised and extended analyses of their previous studies emphasizing policy implications. We have undertaken a review of Lave and Seskin's book to evaluate the methodology used and hence gain some insight into the strength of the conclusions reached. This review concentrates on methodology and its application to establishing and quantifying the association between air quality and health. Beyond simply reviewing the analyses reported in Lave and Seskin's book, we have duplicated and expanded two of the reported analyses. Our detailed reanalysis is presented both to verify reported results, and to illustrate the difficulties encountered in such an analysis.

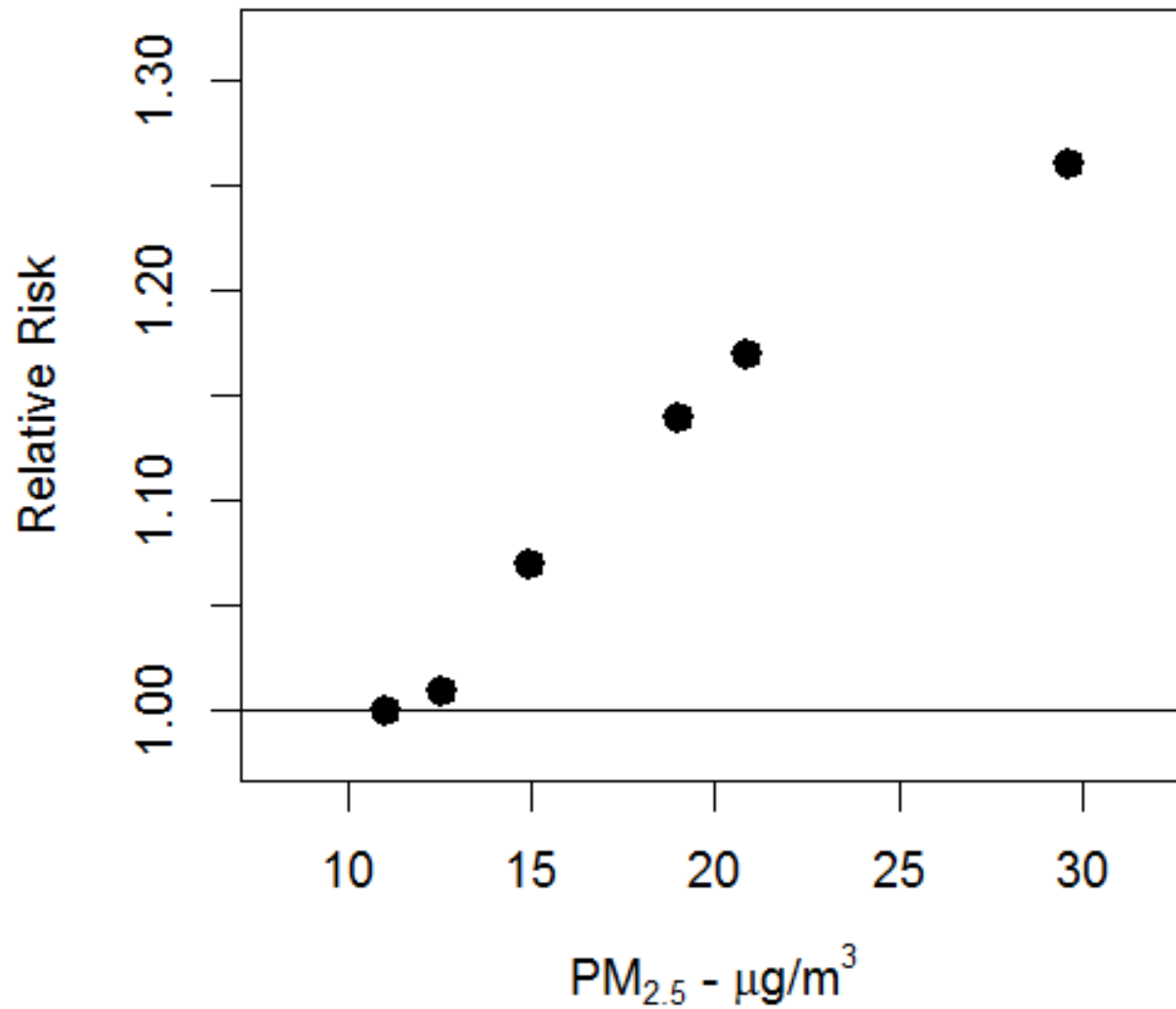
Our overall conclusion is that Lave and Seskin have done a thorough job of reporting and interpreting the various analyses that they performed. Lave and Seskin have made a pioneering effort in showing an association between mortality rates and air pollution. We do not disagree with the conclusion of the existence of an association but have some reservations about their methods of estimating its magnitude.

We were particularly concerned that Lave and Seskin did not fully investigate how well their models fit these data. Our reanalysis results in estimated effects which differ considerably from the values reported by Lave and Seskin. Thus, we conclude that the regression coefficients are quite unstable and so must be used with care. Assessing the relative costs and benefits of reducing air pollution without extensive sensitivity analysis could, therefore, be misleading.

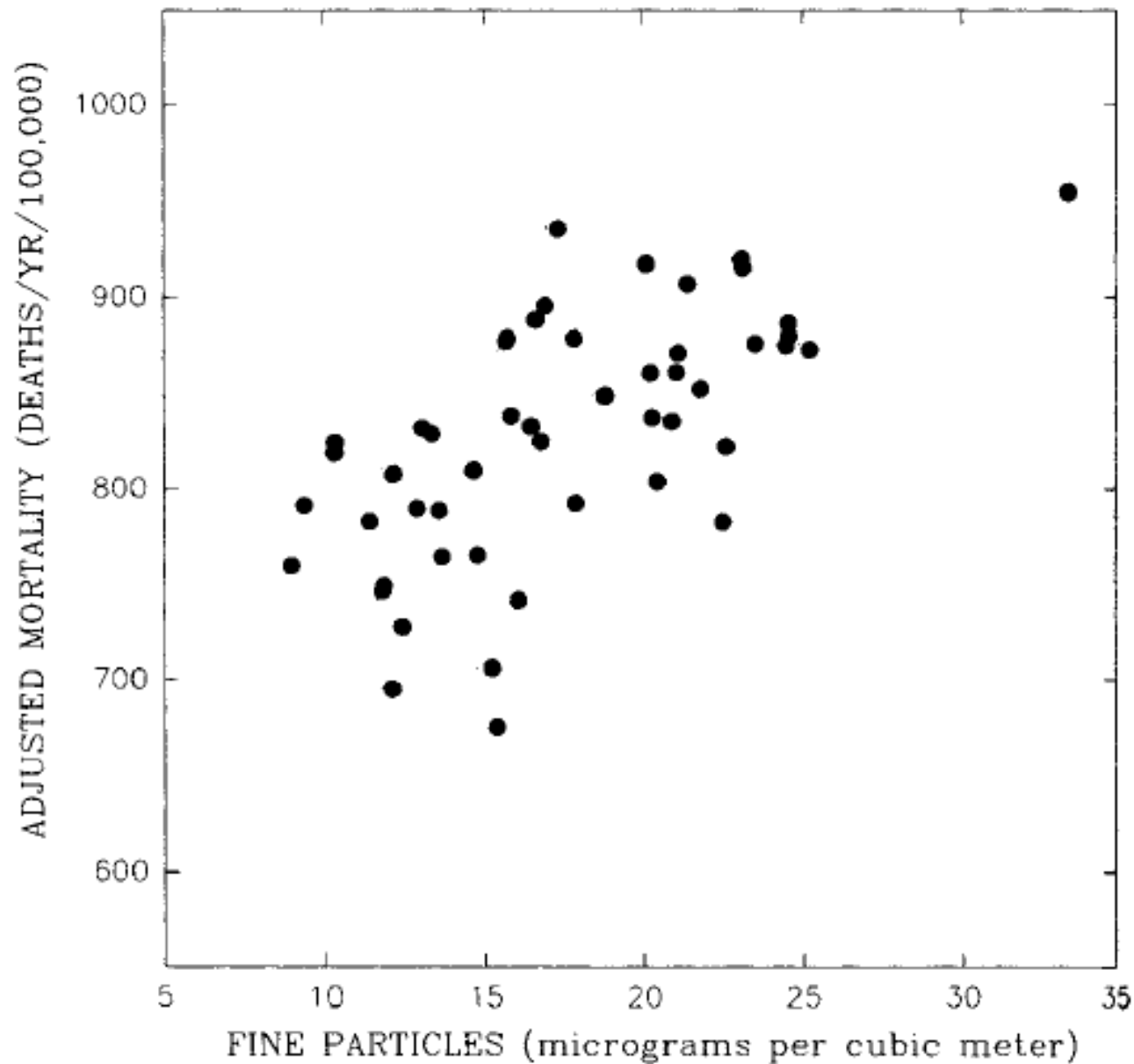
Limitations of Spatially Aggregate Data

- No subject level risk factor information (smoking, diet, BMI)
- Spatial resolution of exposure assignment too coarse

Six Cities Study



***American Cancer Society Cancer Prevention II Cohort
(Pope et al AJRCC 1995)***





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July 2000

SPECIAL REPORT

Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality

A Special Report of the Institute's Particle
Epidemiology Reanalysis Project



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Part I: Replication and Validation

Daniel Krewski, Richard T Burnett, Mark S Goldberg, Kristin Hoover,
Jack Siemiatycki, Michal Abrahamowicz, Warren H White, and Others

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Part I: Replication and Validation

Daniel Krewski, Richard T Burnett, Mark S Goldberg, Kristin Hoover,
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- The Reanalysis Team was able to replicate the original results in both studies using the same data and statistical methods as used by the Original Investigators. The Reanalysis Team confirmed the original point estimates: For the Six Cities Study, they reported the relative risk of mortality from all causes associated with an increase in fine particles of $18.6 \mu\text{g}/\text{m}^3$ as 1.28, close to the 1.26 reported by the Original Investigators. For the ACS Study, the relative risk of mortality from all causes associated with an increase in fine particles of $24.5 \mu\text{g}/\text{m}^3$ was 1.18 in the reanalysis, close to the 1.17 reported by the Original Investigators.



Part I I: Sensitivity Analyses

Daniel Krewski, Richard T Burnett, Mark S Goldberg, Kristin Hoover,
Jack Siemiatycki, Michael Jerrett, Michal Abrahamowicz, Warren H W
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Part II: Sensitivity Analyses

Daniel Krewski, Richard T Burnett, Mark S Goldberg, Kristin Hoover,
Jack Siemiatycki, Michael Jerrett, Michal Abrahamowicz, Warren H White,
and Others

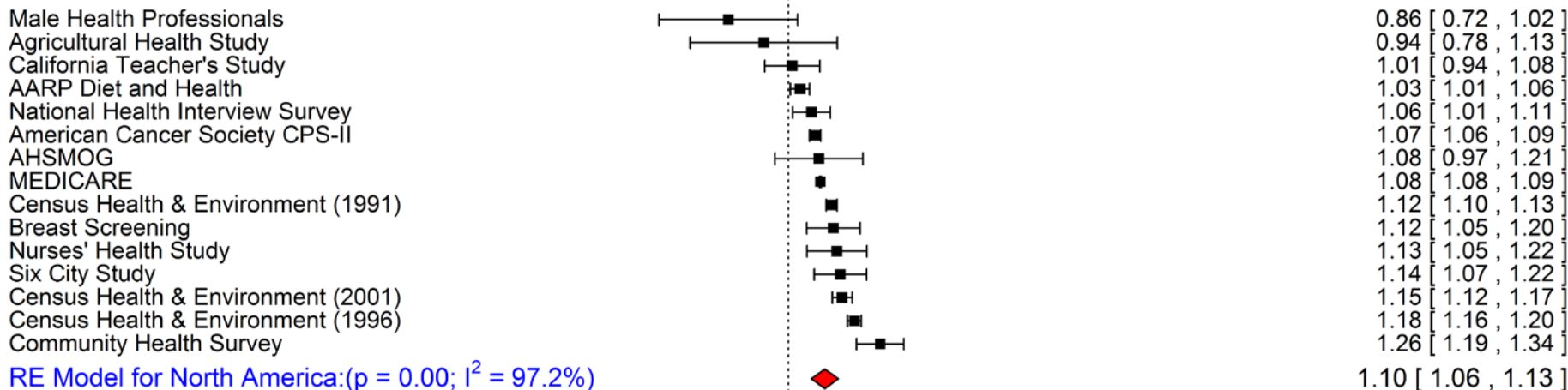
- No single epidemiologic study can be the basis for determining a causal relation between air pollution and mortality.

Global Cohorts of Ambient Fine Particulate Matter and Non-Accidental Mortality

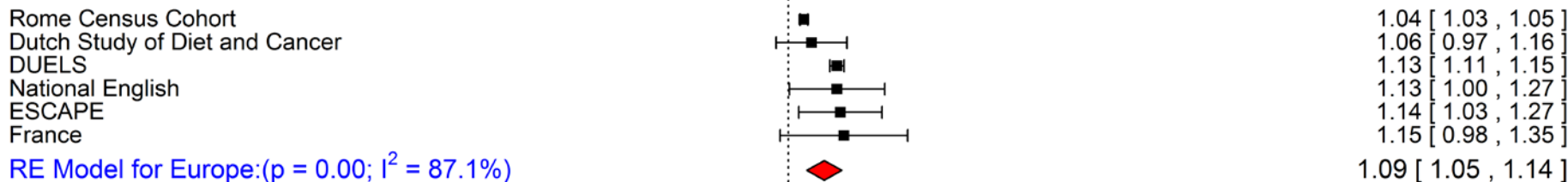
Cohort

Hazard Ratio [95% CI]

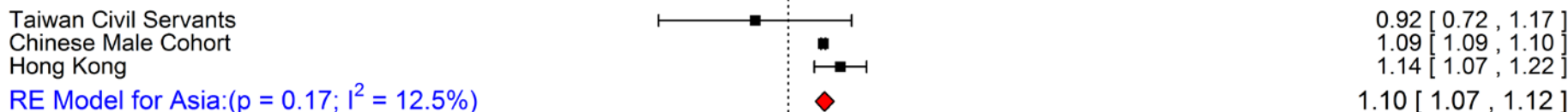
North America



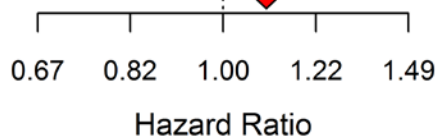
Europe



Asia



RE Model for All Cohorts: (p = 0.00; I² = 97.7%)

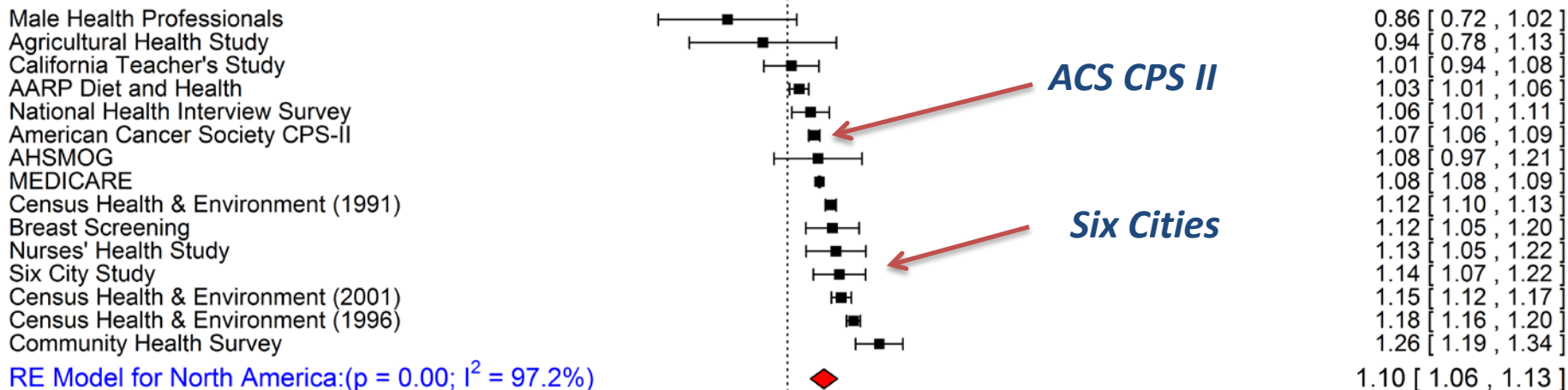


Global Cohorts of Ambient Fine Particulate Matter and Non-Accidental Mortality

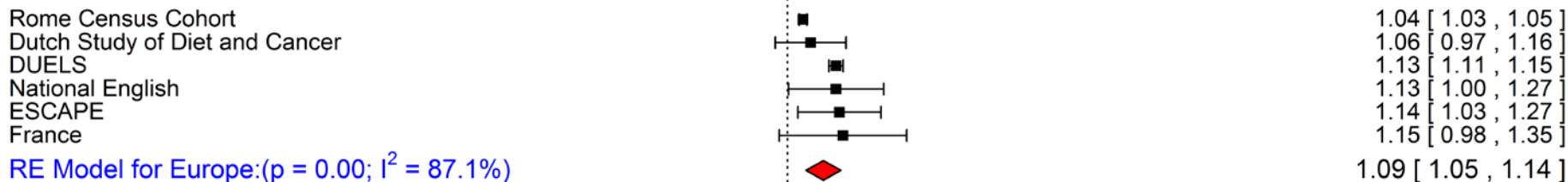
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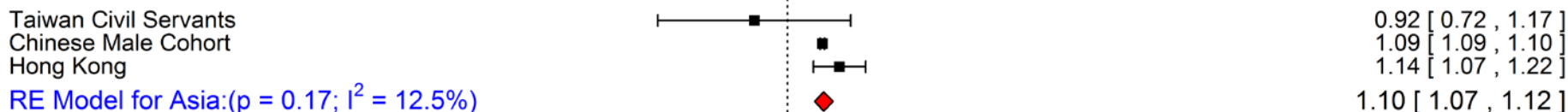
North America



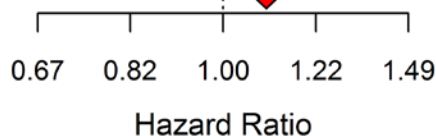
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Asia



RE Model for All Cohorts: (p = 0.00; I² = 97.7%)



Global Cohorts of Ambient Fine Particulate Matter and Non-Accidental Mortality

Cohort

Hazard Ratio [95% CI]

North America

Male Health Professionals
Agricultural Health Study
California Teacher's Study
AARP Diet and Health
National Health Interview Survey
American Cancer Society CPS-II
AHSMOG
MEDICARE
Census Health & Environment (1991)
Breast Screening
Nurses' Health Study
Six City Study
Census Health & Environment (2001)
Census Health & Environment (1996)
Community Health Survey

RE Model for North America: ($p = 0.00$; $I^2 = 97.2\%$)

Europe

Rome Census Cohort
Dutch Study of Diet and Cancer
DUELS
National English
ESCAPE
France

RE Model for Europe: ($p = 0.00$; $I^2 = 87.1\%$)

Asia

Taiwan Civil Servants
Chinese Male Cohort
Hong Kong

RE Model for Asia: ($p = 0.17$; $I^2 = 12.5\%$)

RE Model for All Cohorts: ($p = 0.00$; $I^2 = 97.7\%$)

**National Health
Interview Survey**

MEDICARE

**Publically
Available**

0.86 [0.72 , 1.02]

0.94 [0.78 , 1.13]

1.01 [0.94 , 1.08]

1.03 [1.01 , 1.06]

1.06 [1.01 , 1.11]

1.07 [1.06 , 1.09]

1.08 [0.97 , 1.21]

1.08 [1.08 , 1.09]

1.12 [1.10 , 1.13]

1.12 [1.05 , 1.20]

1.13 [1.05 , 1.22]

1.14 [1.07 , 1.22]

1.15 [1.12 , 1.17]

1.18 [1.16 , 1.20]

1.26 [1.19 , 1.34]

1.10 [1.06 , 1.13]

1.04 [1.03 , 1.05]

1.06 [0.97 , 1.16]

1.13 [1.11 , 1.15]

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1.15 [0.98 , 1.35]

1.09 [1.05 , 1.14]

0.92 [0.72 , 1.17]

1.09 [1.09 , 1.10]

1.14 [1.07 , 1.22]

1.10 [1.07 , 1.12]

1.10 [1.07 , 1.12]

0.67 0.82 1.00 1.22 1.49

Hazard Ratio

Global Cohorts of Ambient Fine Particulate Matter and Non-Accidental Mortality

Cohort

Hazard Ratio [95% CI]

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RE Model for North America: ($p = 0.00$; $I^2 = 97.2\%$)

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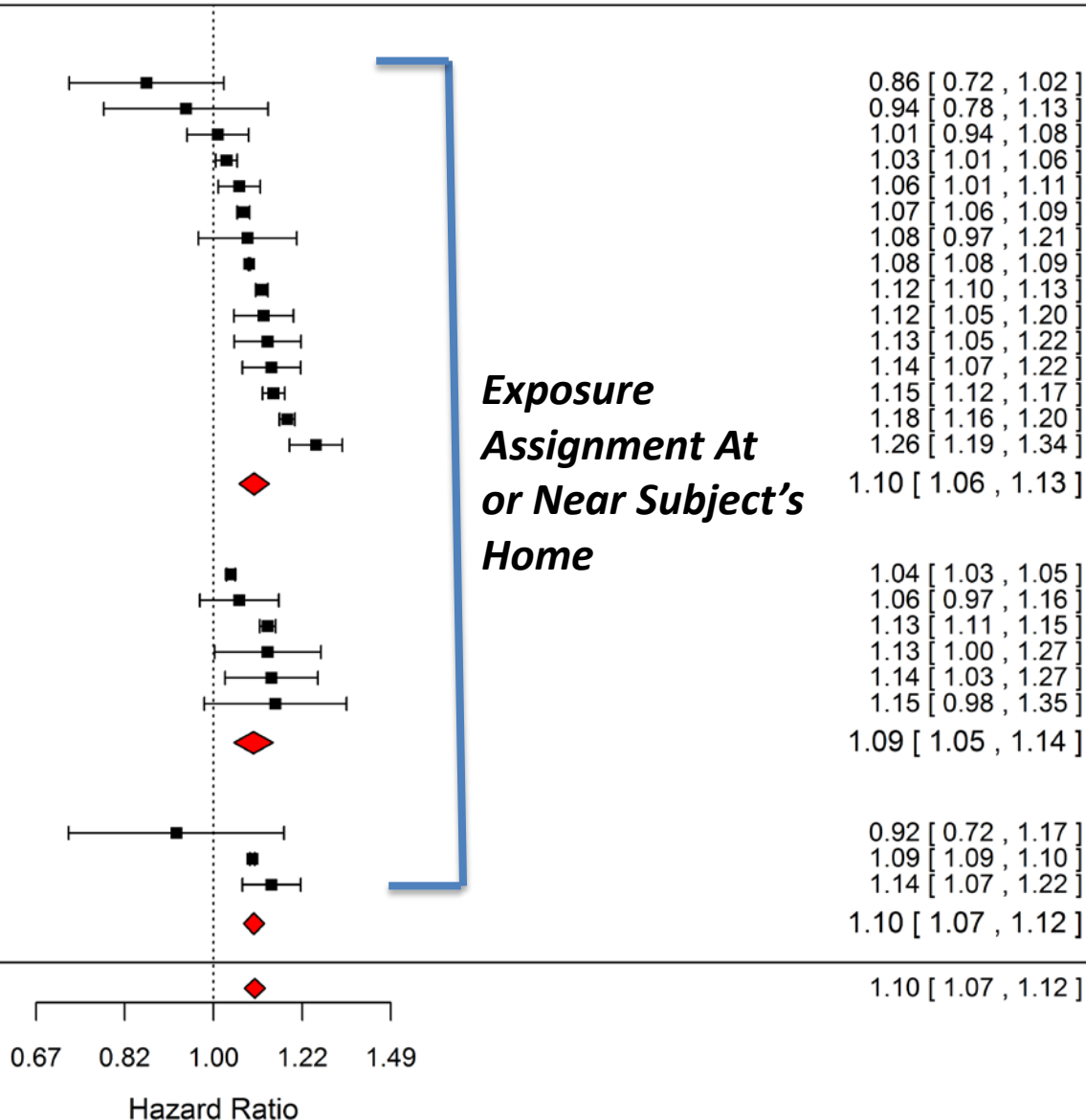
RE Model for Europe: ($p = 0.00$; $I^2 = 87.1\%$)

Asia

Taiwan Civil Servants
Chinese Male Cohort
Hong Kong

RE Model for Asia: ($p = 0.17$; $I^2 = 12.5\%$)

RE Model for All Cohorts: ($p = 0.00$; $I^2 = 97.7\%$)



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Cohort

Hazard Ratio [95% CI]

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RE Model for North America: (p = 0.00; I^2 = 97.2%)

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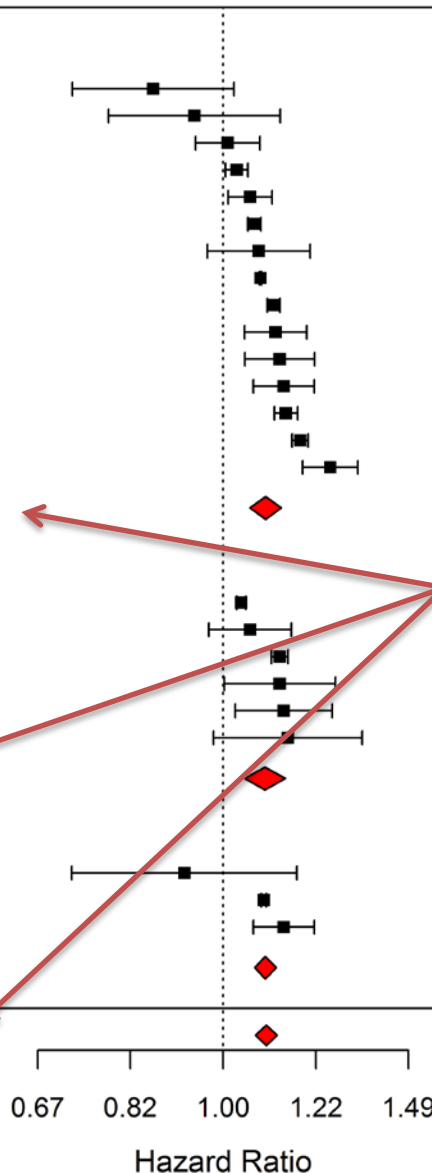
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RE Model for Asia: (p = 0.17; I^2 = 12.5%)

RE Model for All Cohorts: (p = 0.00; I^2 = 97.7%)

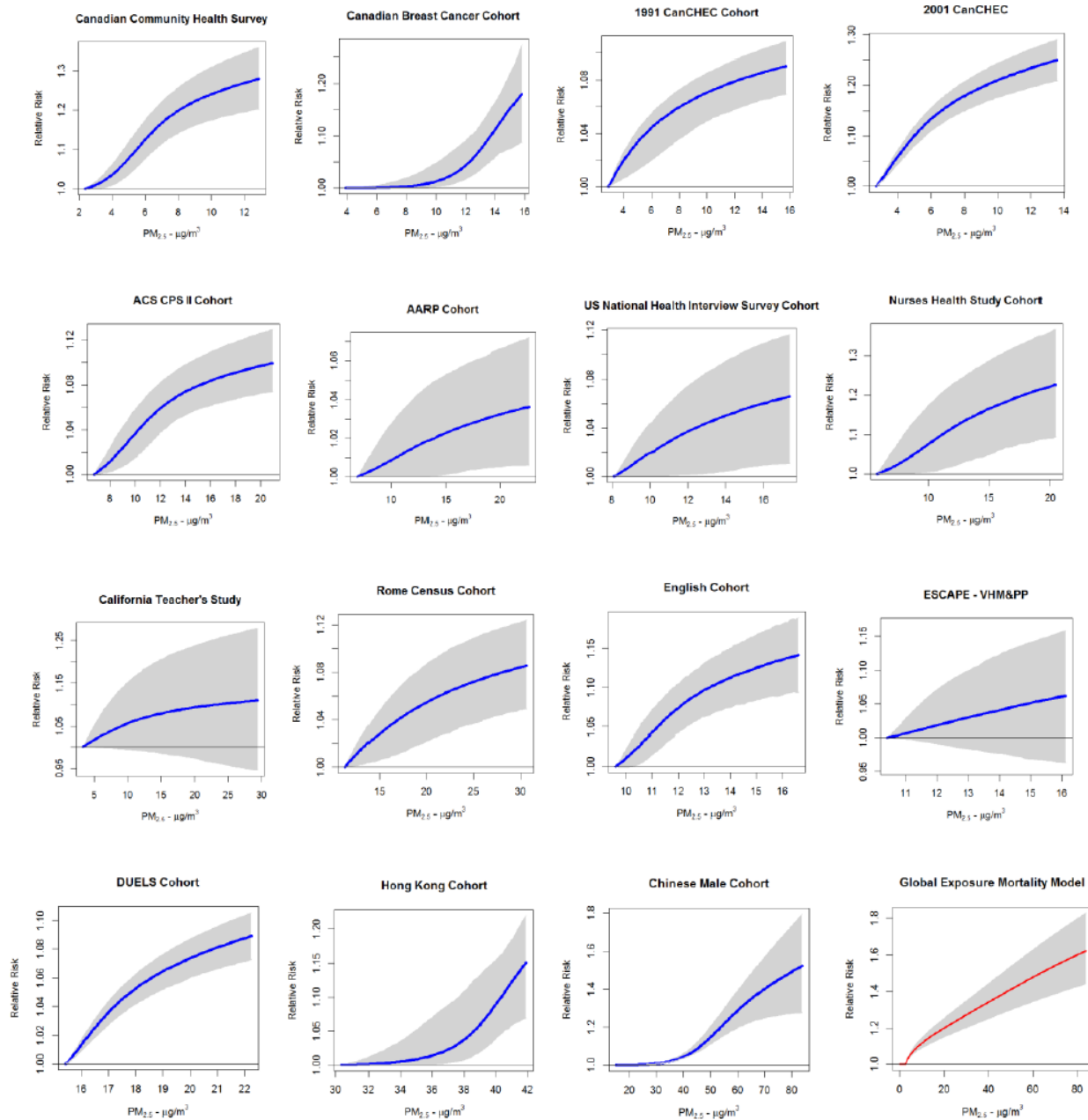


Clear evidence of Heterogeneity in Risk

- Age, Sex
- Location
- Exposure Model
- Statistical Model
- Covariates
- C-R Shape?

Global Mortality and Long-Term Ambient Exposure to Fine Particulate Matter: a New Relative Risk Estimator

Richard Burnett¹, Hong Chen², Mieczyslaw Szyszkowicz¹, Neal Fann³, Bryan Hubbell⁴, C. Arden Pope III⁵, Joshua S. Apte⁶, Michael Brauer⁷, Aaron Cohen⁸, Scott Weichenthal⁹, Jay Coggins¹⁰, Qian Di¹¹, Bert Brunekreef¹², Joey Frostad¹³, Stephen S. Lim¹³, Haidong Kan¹⁴, Katherine D. Walker⁸, George D. Thurston¹⁵, Richard B. Hayes¹⁶, Chris C. Lim¹⁷, Michelle C. Turner¹⁸, Michael Jerrett¹⁹, Daniel Krewski²⁰, Susan Gapstur²¹, W. Diver²¹, Bart Ostro²², Debbie Goldberg²³, Daniel L. Crouse²⁴, Randall Martin²⁵, Paul Peters²⁶, Lauren Pinault²⁷, Michael Tjepkema²⁷, Aaron van Donkelaar²⁵, Paul J. Villeneuve²⁸, Anthony B. Miller²⁹, Peng Yin³⁰, Maigeng Zhou³⁰, Lijun Wang³⁰, Nicole A.H. Janssen³¹, Marten Marra³¹, Richard W. Atkinson³², Hilda Tsang³³, Thuan Quoc Thach³³, John Cannon⁵, Ryan Allen⁵, Jaime Hart³⁴, Francine Laden³⁴, Giulia Cesaroni³⁵, Francesco Forastiere³⁵, Gudrun Weinmayr³⁶, Andrea Jaensch³⁶, Gabriele Nagel³⁶, Hans Concin³⁷, Joseph V. Spadaro³⁸



The Role of Publically Available Data

- ***Benefits***
 - *Provides opportunities for innovative methods of design and analysis*
 - *Help identify critical sources of uncertainty*
 - *Value of innovations more convincing when applied to relevant data!*
- ***Limitations***
 - *To have data made public one must “de-personalize” information*
 - *“alter” age, date of death, cause of death, and location*
 - *Need to understand influence of these “altered” data on effect estimates and uncertainty compared to un-altered information*
 - *Access to personal data available under restrictive environments*
 - *These restricted environments can impose limitations*
- ***Then these innovations will have to be applied to relevant global subject-level data to fully understand their influence***
 - *Develop collaborative efforts among researchers with access to complete subject level information*

Ongoing Studies and Reports under Review and in Press 2016–2017

ACCOUNTABILITY

Improvements in air quality and health outcomes among California Medicaid enrollees due to goods movement actions — Phase 2. *King-Ying Meng, University of California—Los Angeles*

"Impact of emissions changes on air quality and acute health effects in the Southeast, 1993–2012. *Amirabad Russell, Georgia Institute of Technology*

OZONE

Effects of ozone in human volunteers exposed to low levels of ozone in a laboratory. Part 2. *John Balmes, University of California—San Francisco; Philip Bromberg, University of North Carolina—Chapel Hill; Mark Frampton, University of Rochester*

Scavenger receptor B1 regulates oxidized lipid driven pulmonary and vascular inflammation after ozone exposure. *Nymberly Gowdy, East Carolina University*

AIR POLLUTION CONSTITUENTS AND MIXTURES

Epidemiology

"Particulate air pollutants, risk of cognitive disorders, and neuropathology in the elderly. *Jiu-Chuan Chen, University of Southern California*

Air Pollution, Autism spectrum disorders, and brain imaging amongst Children in Europe — the APACHE project. *Mónica Guervá, ISGlobal, Barcelona Institute for Global Health*

Epidemiology at Low Exposures

Identifying the shape of the association between long-term exposure to low levels of ambient air pollution and the risk of mortality: an extension of the Canadian Census Health and Environment Cohort using innovative data linkage and exposure methodology. *Michael Brauer, University of British Columbia*

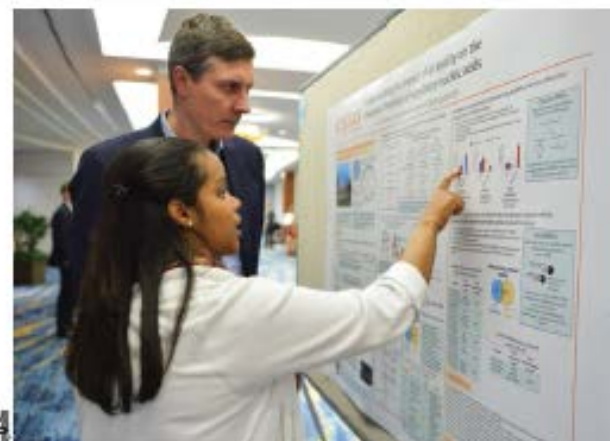
Mortality and morbidity effects of long-term exposure to low-level PM_{2.5}, black carbon, NO₂, and O₃: an analysis of European cohorts. *Bert Brunekreef, Utrecht University*

Assessing adverse health effects of long-term exposure to low levels of ambient pollution. *Francesca Dominici, Harvard University*

Emissions and Exposure Assessment

"The Hong Kong D3D study: a dynamic three-dimensional exposure model for Hong Kong. *Benjamin Barratt, King's College London*

Enhancing models and measurements of traffic-related air pollutants for health studies using Bayesian melding. *Stuart Batterman, University of Michigan*



Lyle Contreras, University of Texas—Austin; and two Pangea, Texas A&M University and HEI Research Committee.

"Report in the HEI review process as of June 30, 2017

Ongoing Studies and Reports under Review and in Press 2016–2017

Epidemiology at Low Exposures

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Thank You