Household Air Pollution and Chronic Disease Among the Bottom Billion

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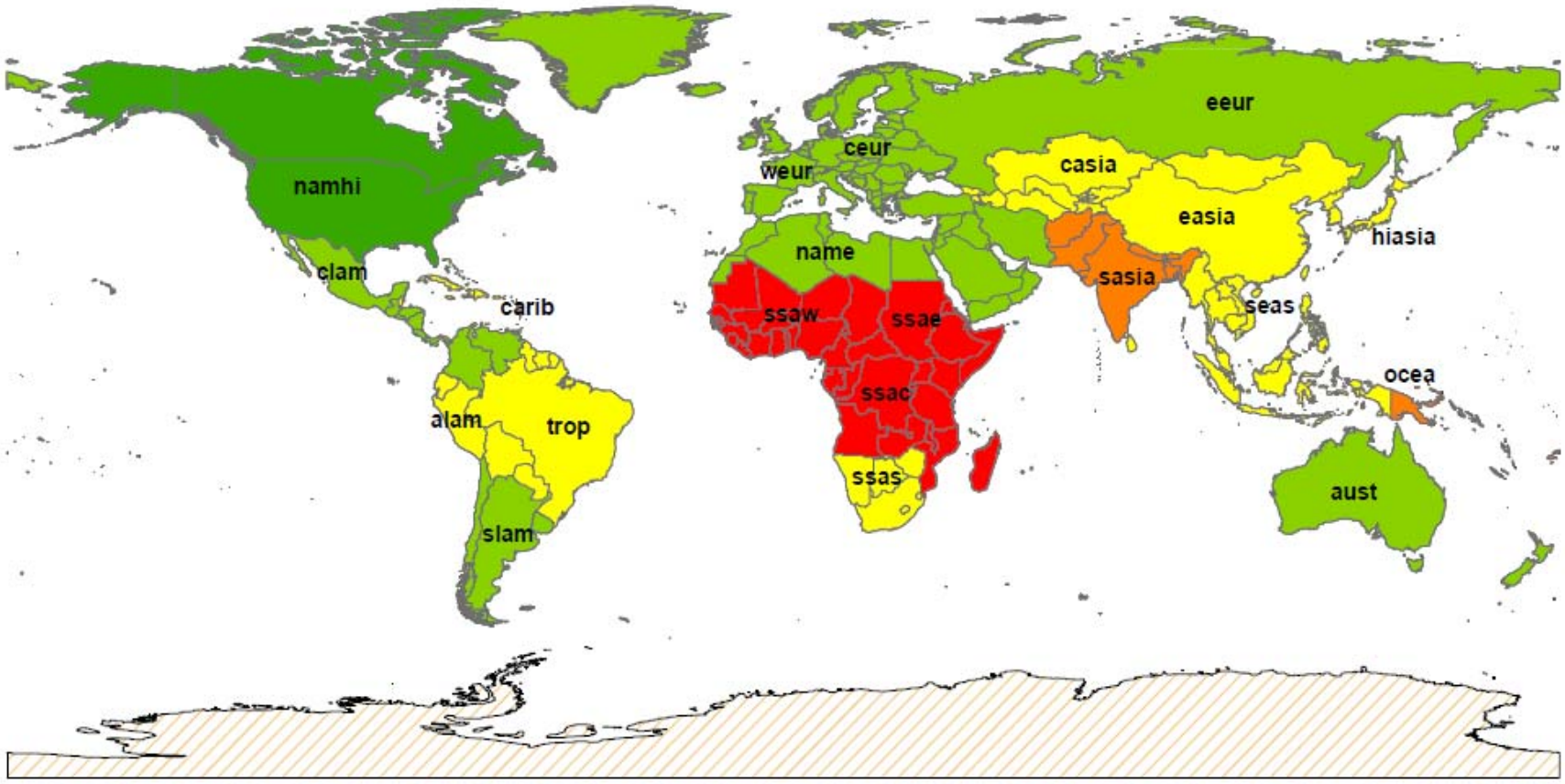
Tackling the Endemic Non-Communicable Diseases of the Bottom Billion
Harvard University, March 3, 2011

What NCD risk factor is shared by all billion people in the bottom billion?

- Diet?
- Physical inactivity?
- Smoking?
- Appropriate infectious agents?
- No
- So ubiquitous, in fact, that it is one of the best quick indicators of poverty?

Households Using Solid Cooking Fuels

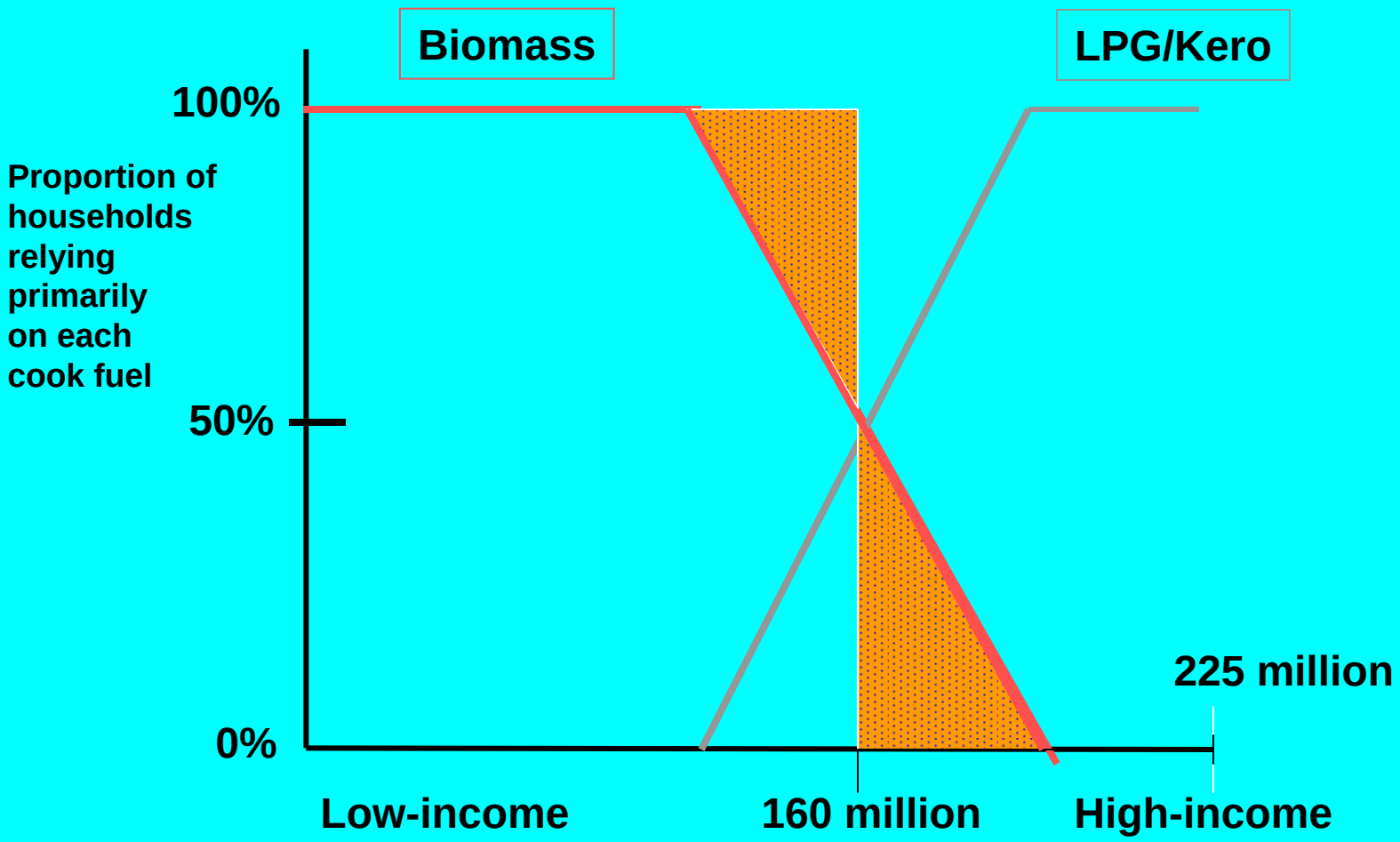


% of HH Exposed to HAP

< 5	51 - 75
6 - 20	76 - 93
21 - 50	No Data

For 2005, CRA-10 preliminary

Proportion of Household Meals Cooked by Fuel Type in India



2005 NFHS

Road Map

- Intro – what's wrong with biomass smoke?
- COPD – several new meta-analyses
- Lung cancer – new meta-analyses for both biomass and coal smoke [not further discussed].
- Cataracts/opacity – a major burden
- LBW – new meta-analysis, life-long chronic risks?
- Cardiovascular disease – interpolation backed up by physiological evidence
- "Epidemiologic" transition – do NCD risks rise with development?

Woodsmoke is natural – how can it hurt you?

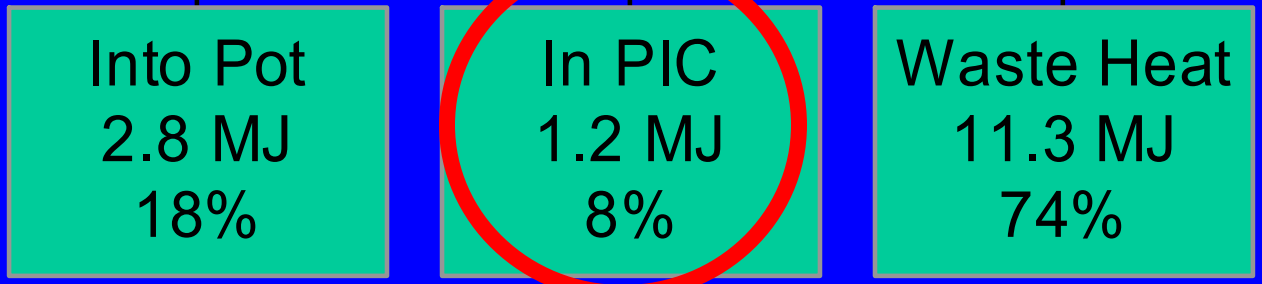
Or, since wood is mainly just carbon, hydrogen, and oxygen, doesn't it just change to CO_2 and H_2O when it is combined with oxygen (burned)?

Reason: the combustion efficiency is far less than 100%

Energy flows in a well-operating traditional wood-fired Indian cooking stove

A Toxic Waste Factory!!

Typical biomass cookstoves convert 6-20% of the fuel carbon to toxic substances



PIC = products of incomplete combustion = CO, HC, C, etc.

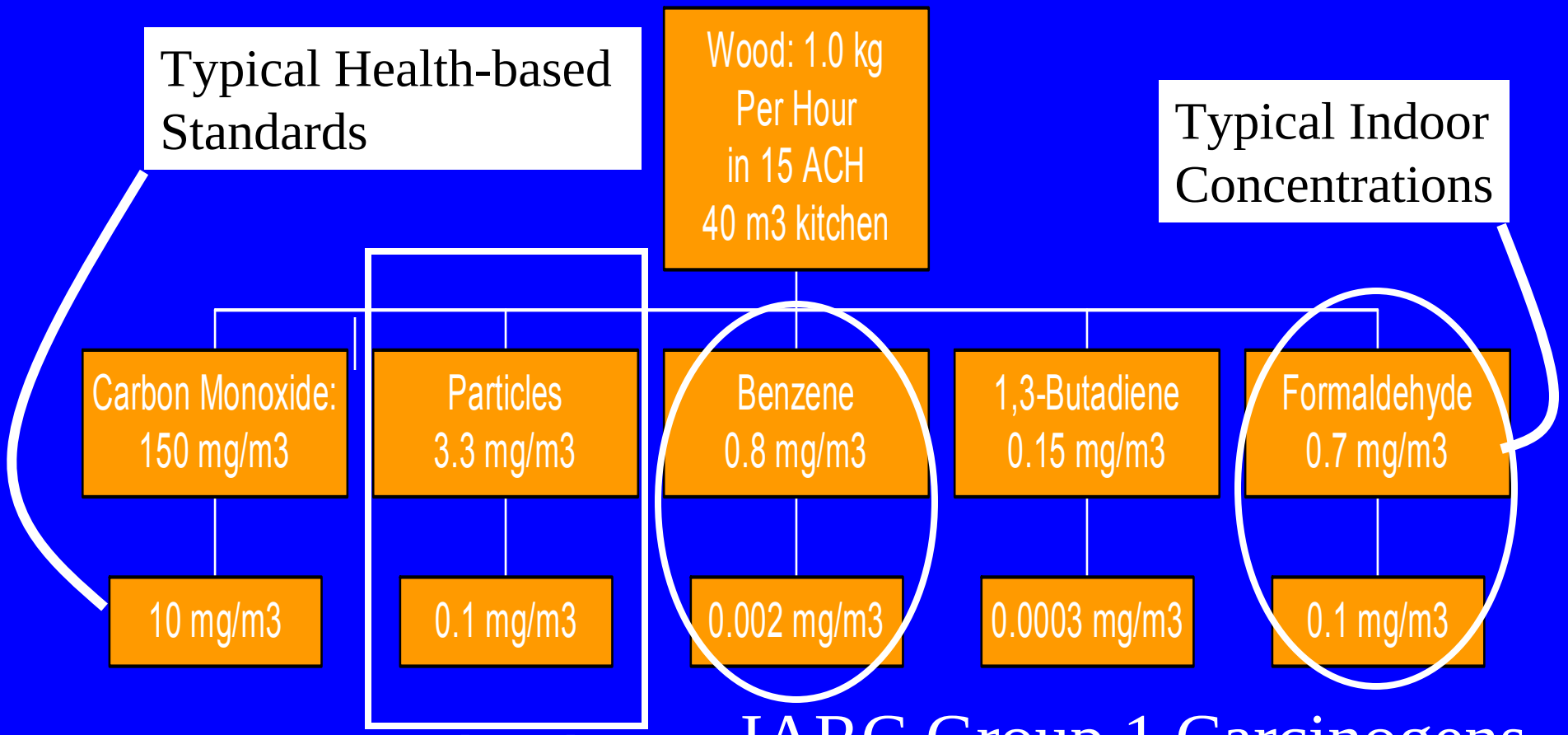
Source: Smith, et al., 2000

Toxic Pollutants in Biomass Fuel Smoke from Simple (poor) Combustion

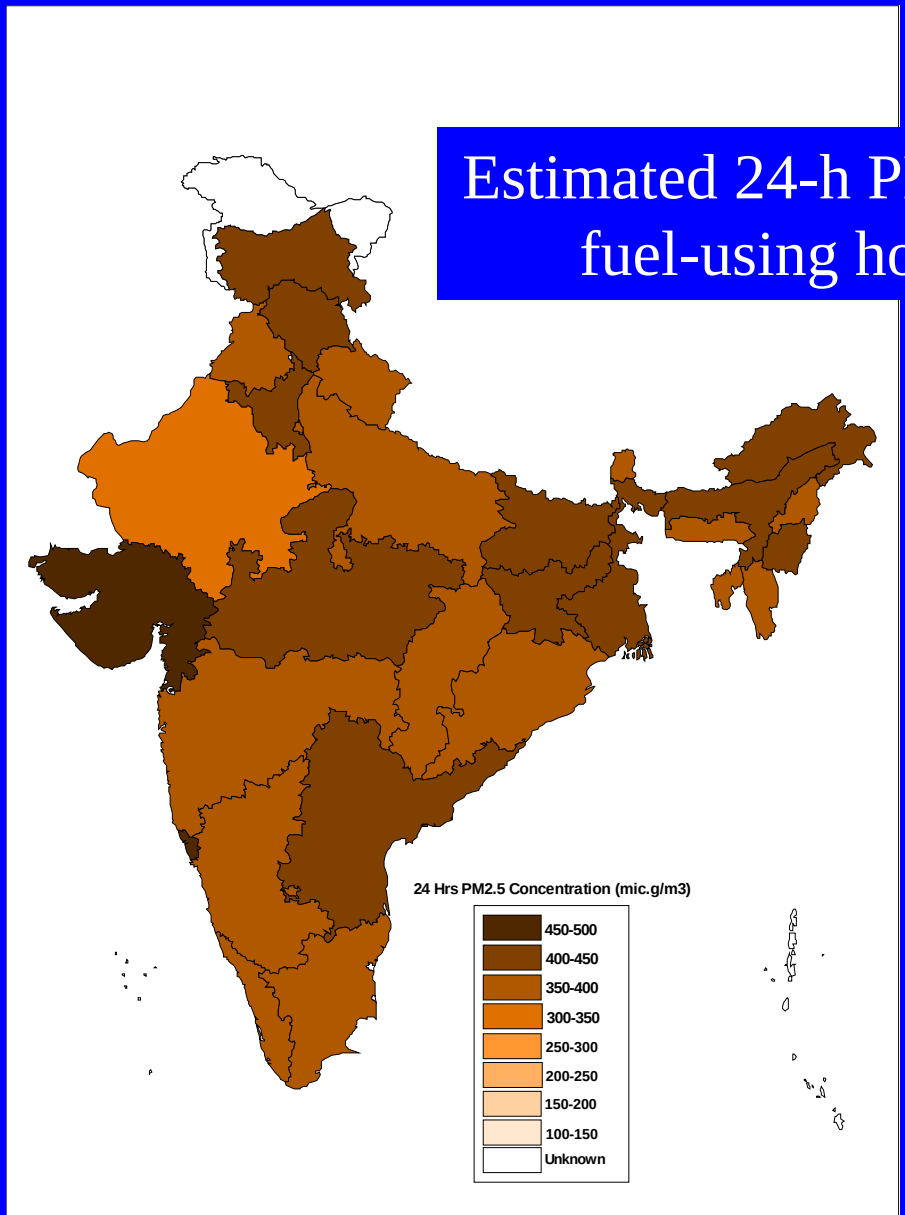
- Small particles, CO, NO_2
- Hydrocarbons
  - 25+ saturated hydrocarbons such as *n-hexane*
  - 40+ unsaturated hydrocarbons such as *1,3 butadiene*
  - 28+ mono-aromatics such as *benzene & styrene*
  - 20+ polycyclic aromatics such as *benzo(α)pyrene*
- Oxygenated organics
  - 20+ aldehydes including *formaldehyde* & *acrolein*
  - 25+ alcohols and acids such as *methanol*
  - 33+ phenols such as *catechol* & *cresol*
  - Many quinones such as *hydroquinone*
  - Semi-quinone-type and other radicals
- Chlorinated organics such as *methylene chloride* and *dioxin*

Source: Naeher et al, *J Inhal Tox*, 2007

Health-Damaging Air Pollutants From Typical Woodfired Cookstove in India.



Household Air Pollution Comparative Risk Assessment, 2011
Preliminary Estimates for India



Estimated 24-h $PM_{2.5}$ for solid-fuel-using households

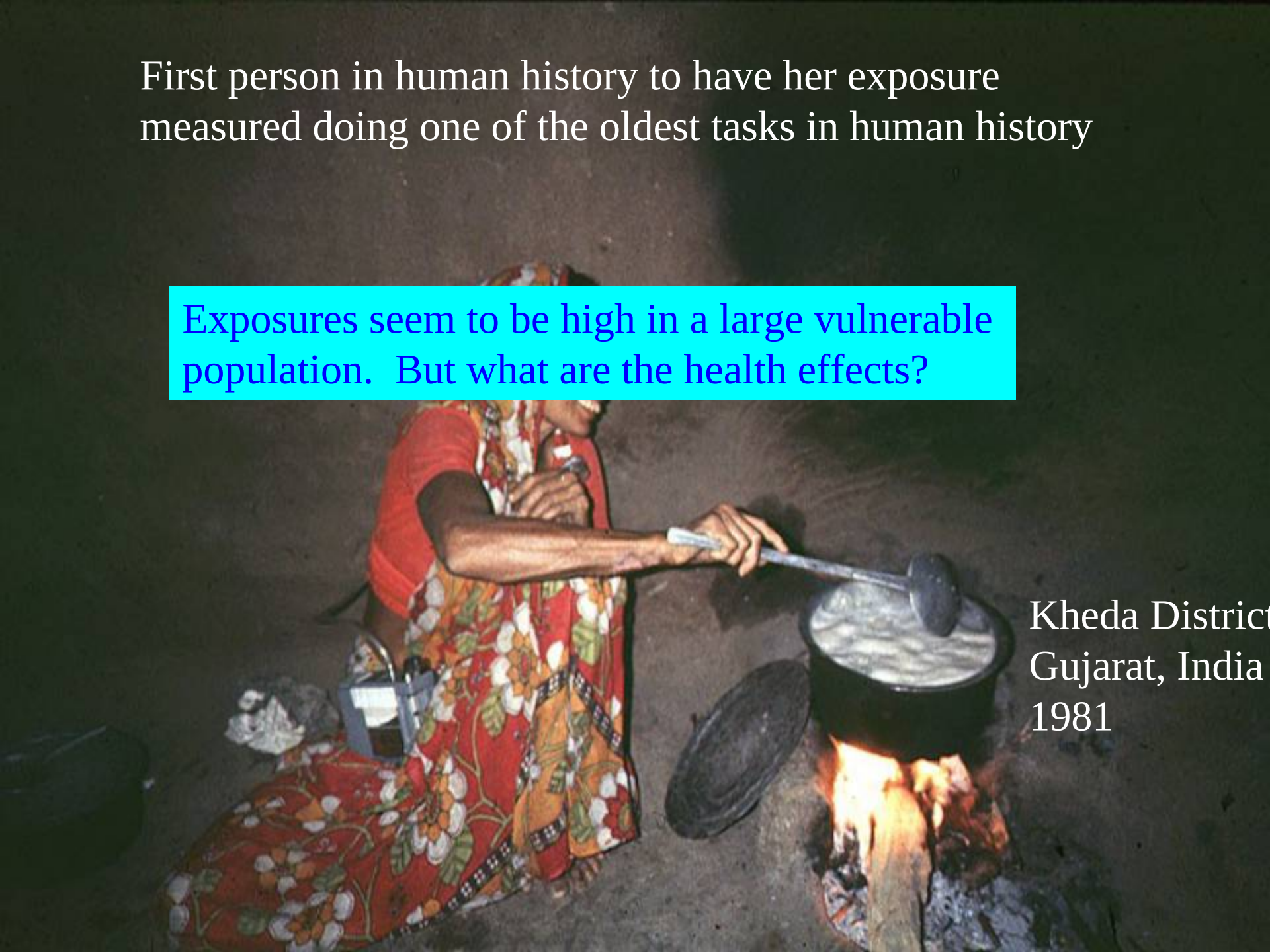
~400 ug/m3 mean

EPA standard
= 15ug/m3
WHO AQG
= 10 ug/3

Balakrishnan et al., in prep

First person in human history to have her exposure measured doing one of the oldest tasks in human history

Exposures seem to be high in a large vulnerable population. But what are the health effects?



Kheda District
Gujarat, India
1981

Diseases for which we have epidemiological studies - 2011

ALRI/
Pneumonia
(meningitis)

Low birth weight

Stillbirth

Cognitive Impairment?

Asthma?

Birth defects?

Chronic obstructive lung disease

Cancer
(lung, NP, cervical, aero-digestive)

Blindness
(cataracts, opacity)

Tuberculosis?

Heart disease*
Blood pressure
ST-segment

*Interpolated

Biomass Smoke and COPD: Meta-analysis

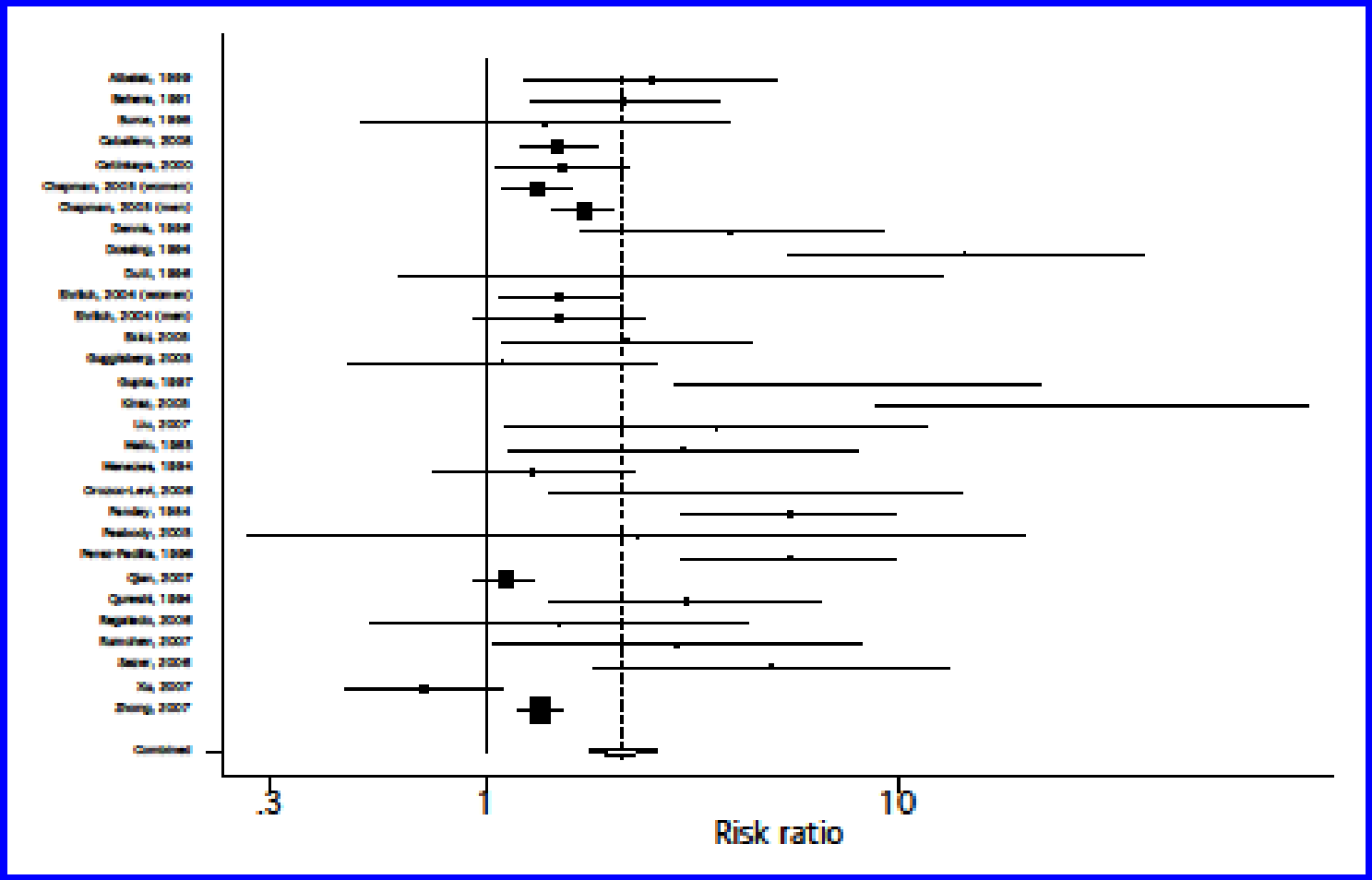
- Summary RR estimates calculated using both fixed effects and random effects models
- Heterogeneity among studies assessed using general variance-based methods
- Publication bias assessed using funnel plot, Eggers and Begg's tests

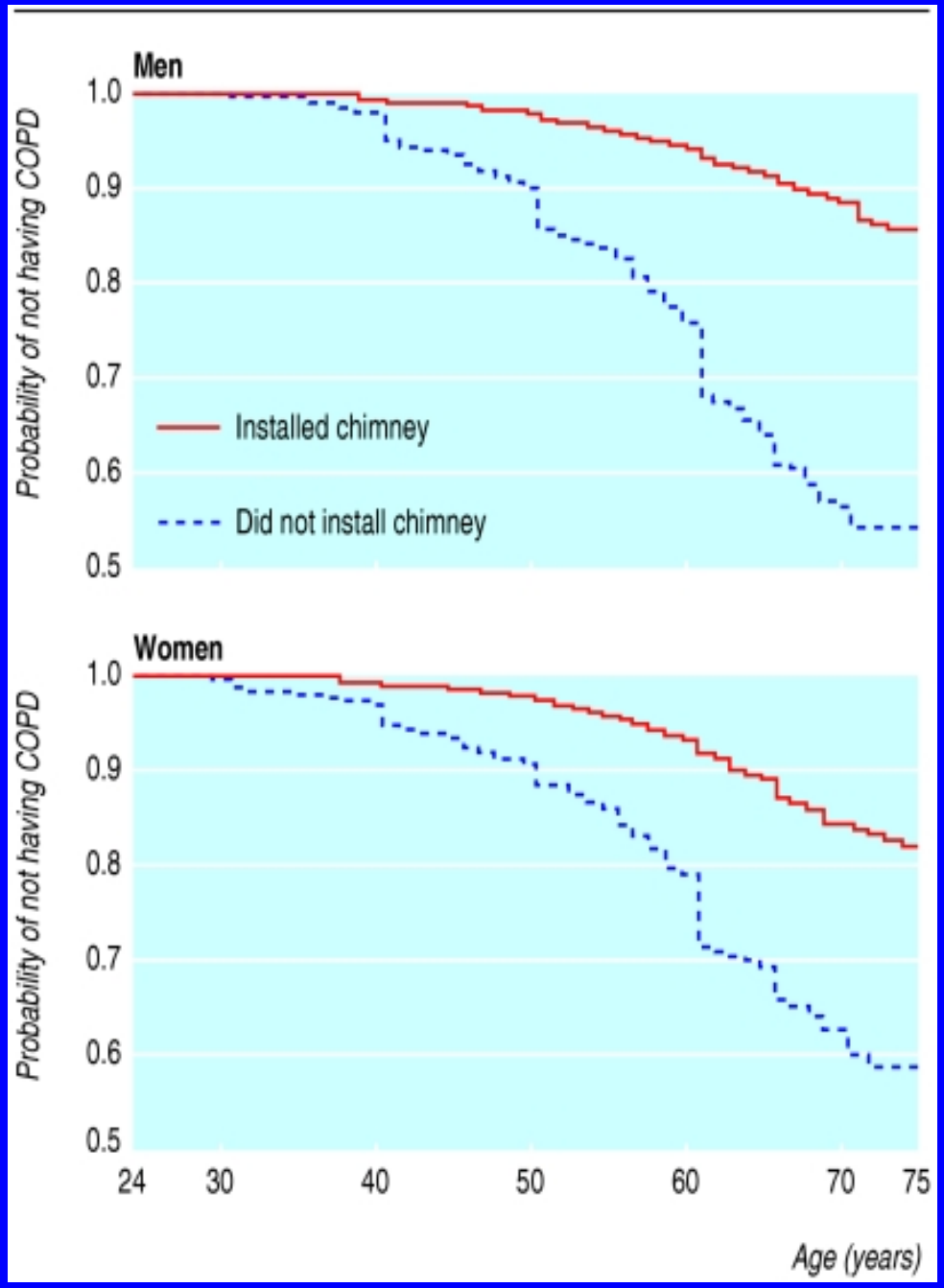
Exposure Assessment Used for Analysis	# of Final Studies
Fuel Type	19
Coal Only	7
Wood Only	6
Stove Type	2
Years Exposed	5
Urban v. Rural	2

Outcome Assessment	# of Final Studies
Chronic Bronchitis, clinical definition	20
COPD, FEV_1/FVC <0.70	4
Previous Physician Diagnosis	4

Forest Plot for All Studies Included in Meta-analysis

- Random effects model was used to account for significant heterogeneity between studies X^2=150.329, *df*=29 (*p*=0.000)
- Overall effect measure for all studies, OR=2.140 (1.777, 2.577)





Risk of COPD: Vented vs. unvented coal stoves

Xuan Wei County
China,
retrospective cohort,
1976-1992,
20,453 subjects
81% added chimneys

Chapman et al. Br Med J 2005; 331: 1050.

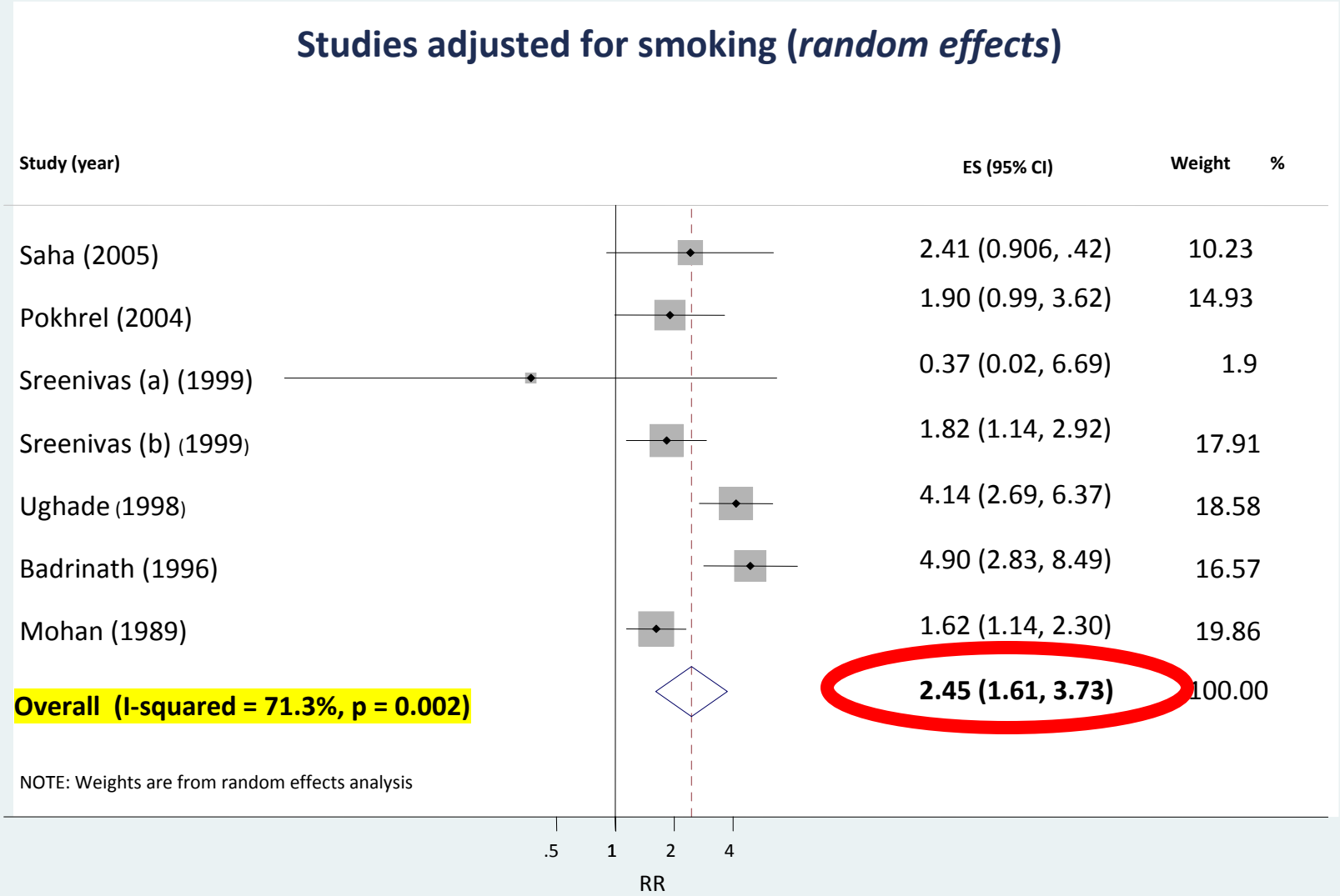
Cataracts

- Major burden of disease in developing countries
- In South Asia, 2.8% of total DALYs in 2005
- Half that of ischaemic heart disease
- Roughly same as TB or stroke
- Greater than COPD or maternal conditions
- Women suffer 40% more than men

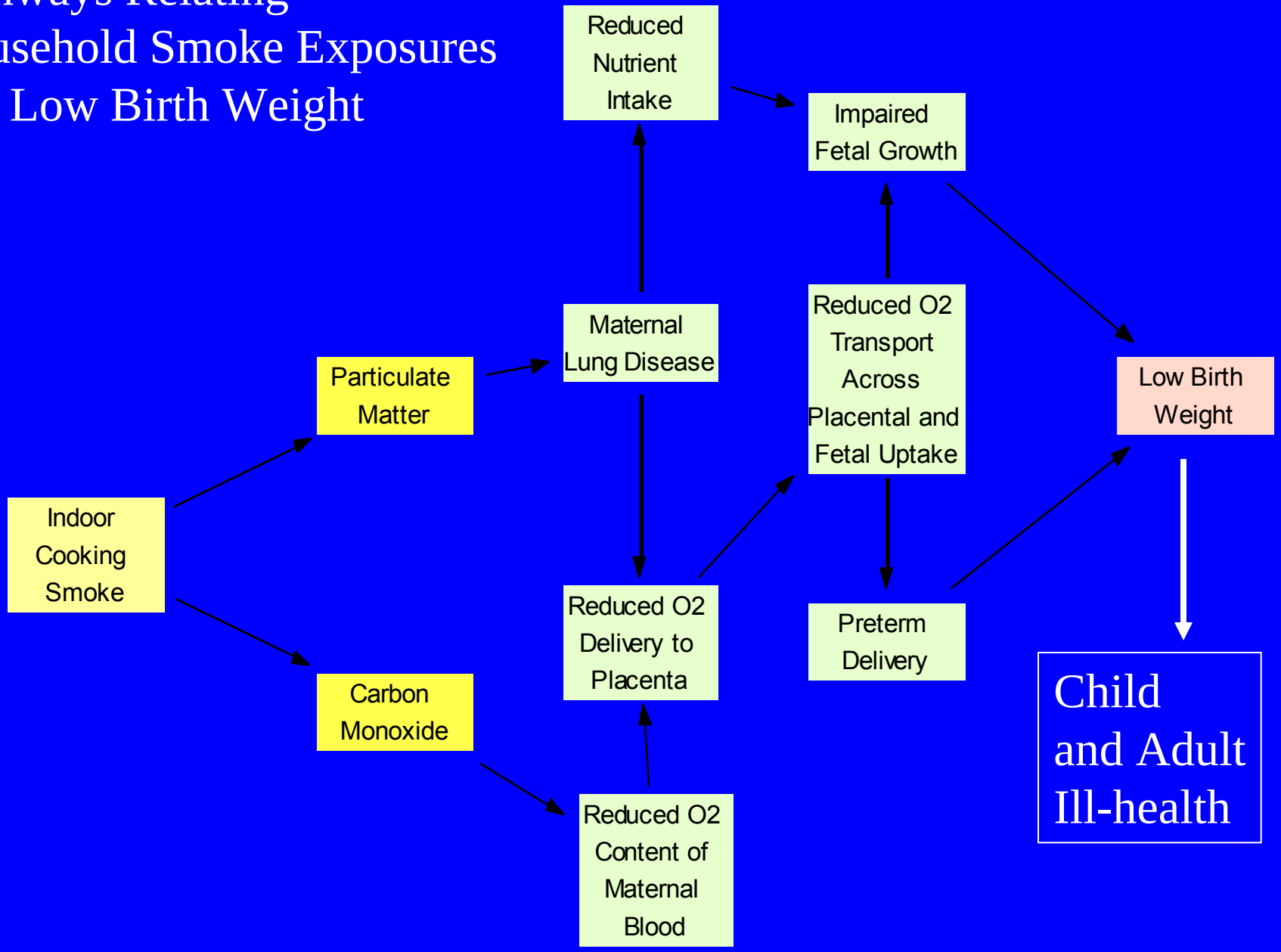
HAP and cataract: biological plausibility

- Cataracts have several known risk factors: UV, diabetes, tobacco smoke
- Napthalene, a prevalent product of incomplete biomass combustion, is a reactive oxidative species (ROS) causing oxidative stress & damage to the eye,
- Cataract outcomes have been shown in rabbits and cows with prolonged exposure or under high doses
- Recent study in Nepal shows exposure-response with biomass smoke exposure and lens opacity, a preclinical indicator of cataracts.

Summary of 7 (of 9 total) studies



Pathways Relating Household Smoke Exposures and Low Birth Weight

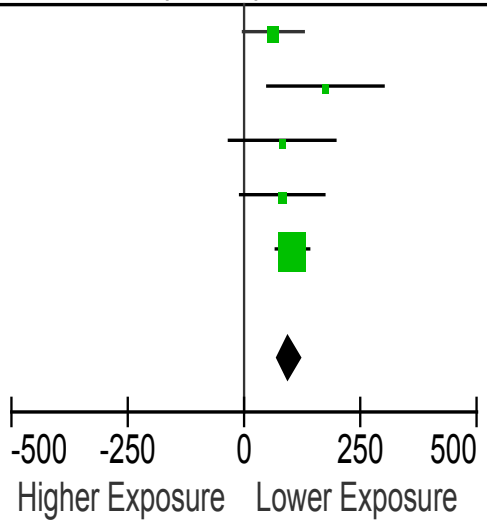


Pooled birth weight difference (low minus high exposure): Adjusted estimates

Study or Subgroup	Lower Exposure Mean	SD	Total	Higher Exposure Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Boy 2002	2,835	533	357	2,772	525	871	18.5%	63.00 [-2.36, 128.36]
Mishra 2004	3,271	1,448	766	3,096	1,429	1535	5.0%	175.00 [50.00, 300.00]
Siddiqui 2008	2,812	404	80	2,730	385	108	6.0%	82.00 [-32.50, 196.50]
Thompson 2005	2,805	579	366	2,723	573	268	9.6%	82.00 [-8.69, 172.69]
Tielsch 2009	2,819	453	646	2,715	420	8958	60.9%	104.00 [68.00, 140.00]
Total (95% CI)			**2215**			**11740**	**100.0%**	**96.58 [68.49, 124.67]**

Heterogeneity: Chi² = 2.85, df = 4 (P = 0.58); I² = 0%

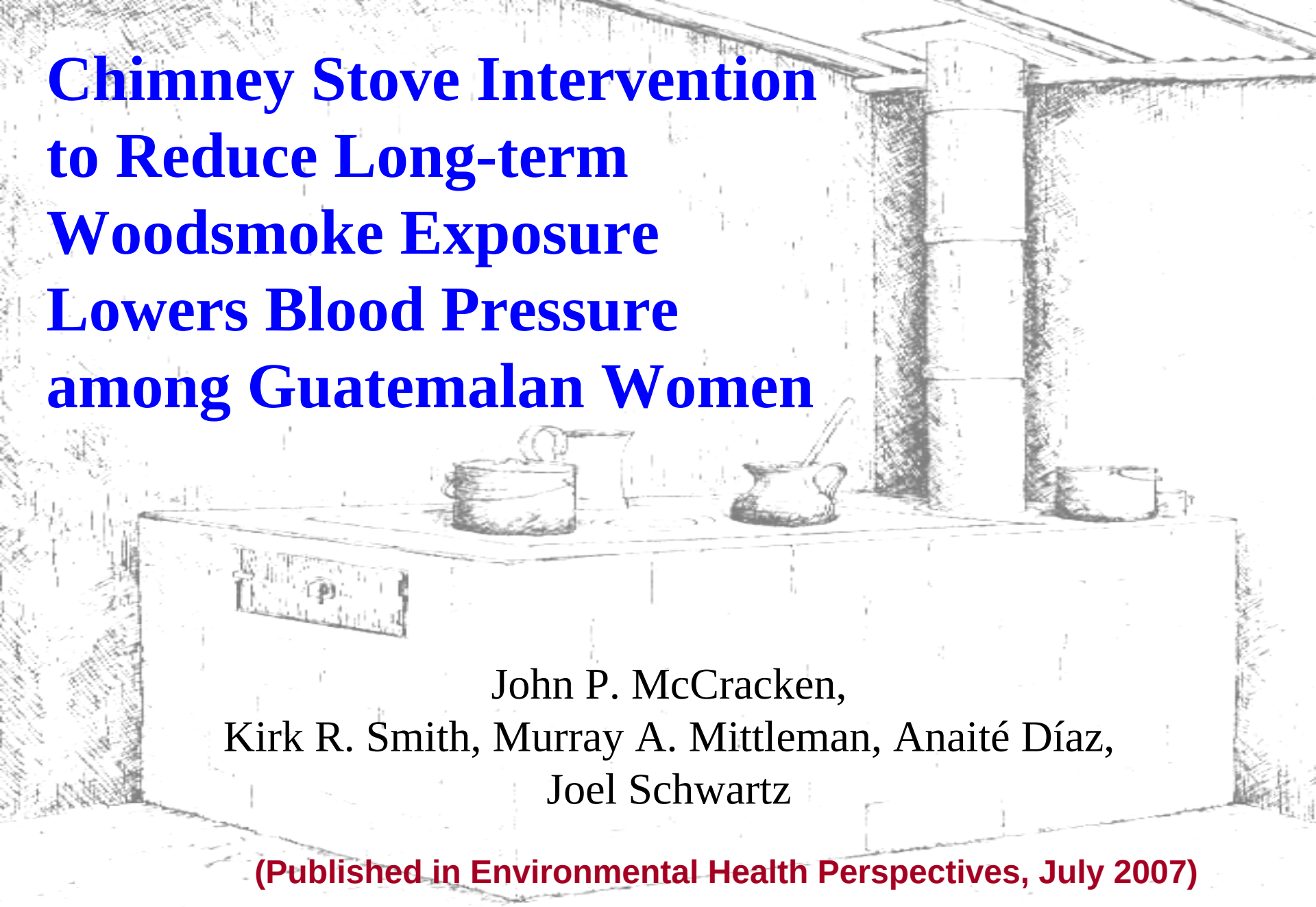
Test for overall effect: Z = 6.74 (P < 0.00001)



All estimates: +96.6g (68.5, 124.7)

Excluding self-reports +93.1g (64.6, 121.6)

Chimney Stove Intervention to Reduce Long-term Woodsmoke Exposure Lowers Blood Pressure among Guatemalan Women



John P. McCracken,
Kirk R. Smith, Murray A. Mittleman, Anaité Díaz,
Joel Schwartz

(Published in Environmental Health Perspectives, July 2007)

Study Design

- Study population
  - Eligible: Women ≥ 38 years, cooking daily
  - Excluded: pregnant, breastfeeding
- Two follow-up periods
  - Randomized trial period (7/03-12/04)
  - Echo-intervention period (3/04-3/05)

Personal $PM_{2.5}$

SBP and DBP

Between-Groups Results During Randomization

	Number of subjects (measures)		Adjusted mean difference*		
	Control group	Intervention group	Estimate	95% CI	p-value
SBP	71 (111)	49 (115)	-3.7	-8.1, 0.6	0.10
DBP	71 (111)	49 (115)	-3.0	-5.7, -0.4	0.02

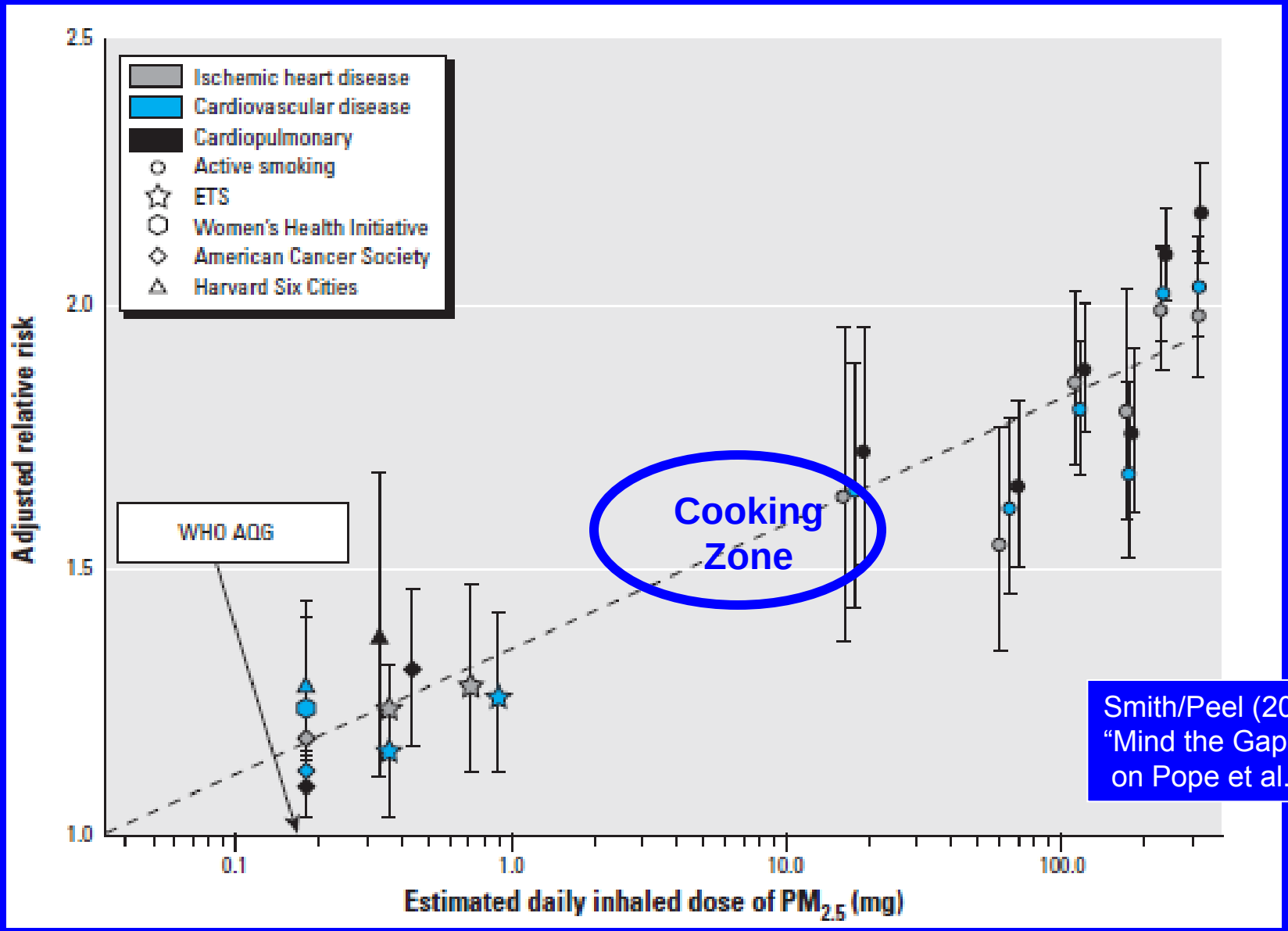
* Adjusted for age, body mass index, daily temperature, season, day of the week, time of day, use of wood-fired sauna, household electricity, an asset index, ever smoking, and secondhand tobacco smoke exposure

Before-and-After Results

	Number of subjects (measures)		Adjusted mean difference*		
	Trial period	Echo-intervention	Estimate	95% CI	p-value
SBP	55 (88)	55 (65)	-3.1	-5.3, -0.8	0.01
DBP	55 (88)	55 (65)	-1.9	-3.5, -0.4	0.01

* Adjusted for age, body mass index, daily temperature, season, day of the week, time of day, use of wood-fired sauna, household electricity, an asset index, ever smoking, and secondhand tobacco smoke exposure

Heart Disease and Combustion Particle Doses



Smith/Peel (2010), "Mind the Gap" based on Pope et al. (2009)

Argument from consistency across combustion particle exposures for CVD

- Fine combustion particles are best measure of risk in each setting and seem to have similar effects per unit mass across the four source types
  - Three are mainly biomass
  - Outdoor air pollution contains significant biomass particles
  - Probably difference by outcome, however – e.g., LBW and lung cancer may be related to other components as well
- Remarkable consistency across 3 orders of magnitude of dose measured in mg/day of $PM_{2.5}$
- Where household air pollution has no direct epi data, seems reasonable to interpolate for outcomes where there are well established effects at both lower and higher doses.

Indian National Biomass Cookstove Initiative – Dec 2, 2009

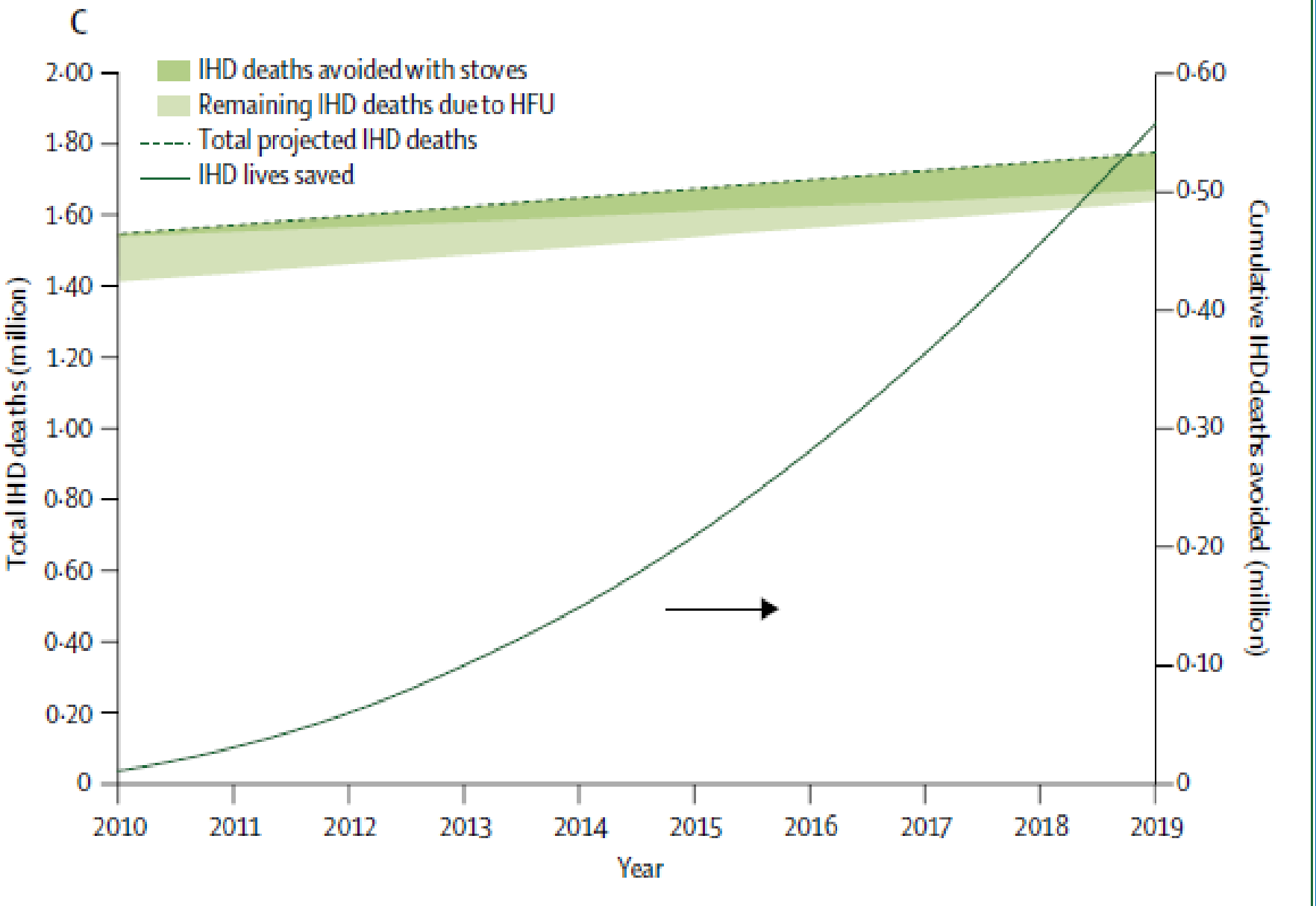
- ***"Our aim is to achieve the quality of energy services from cookstoves [for all Indian households] comparable to that from other clean energy sources such as LPG."***

Analysis of total health benefits of 150 million advanced stoves introduced over 10 years in India

Wilkinson, Smith, et al., the Lancet 374:1917-29, 2009

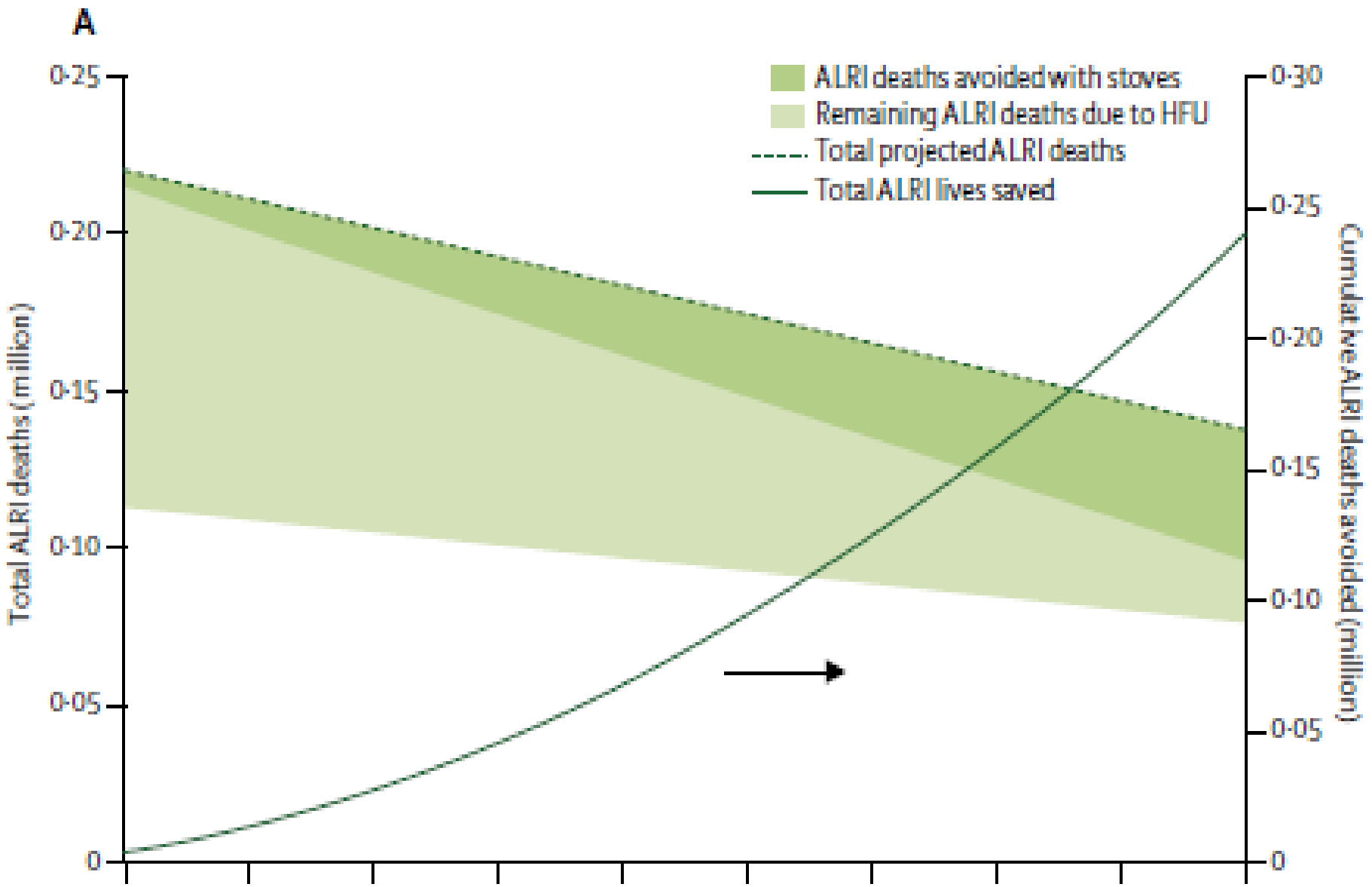
Ischaemic Heart Disease

THE LANCET



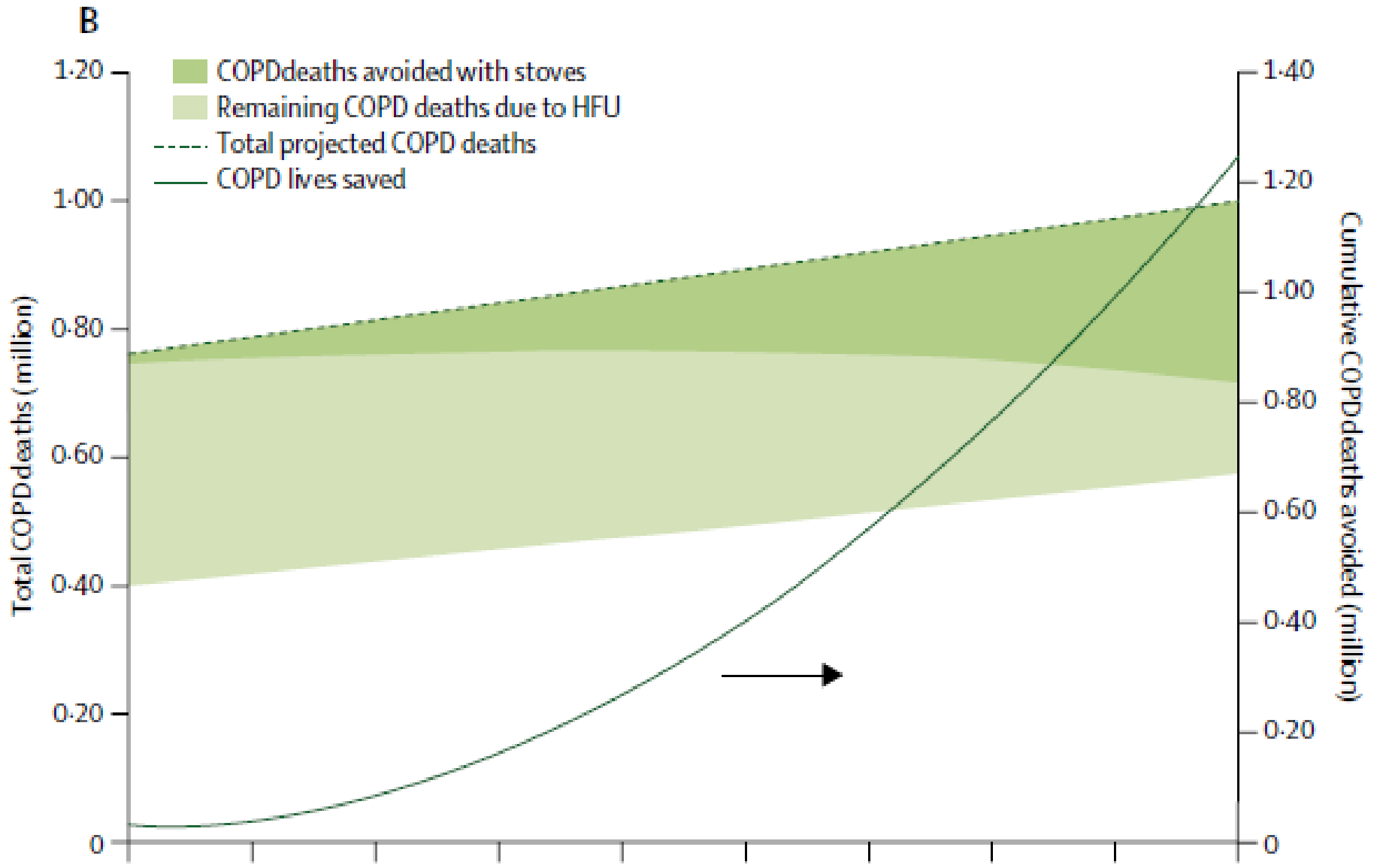
ALRI < 5 years

THE LANCET



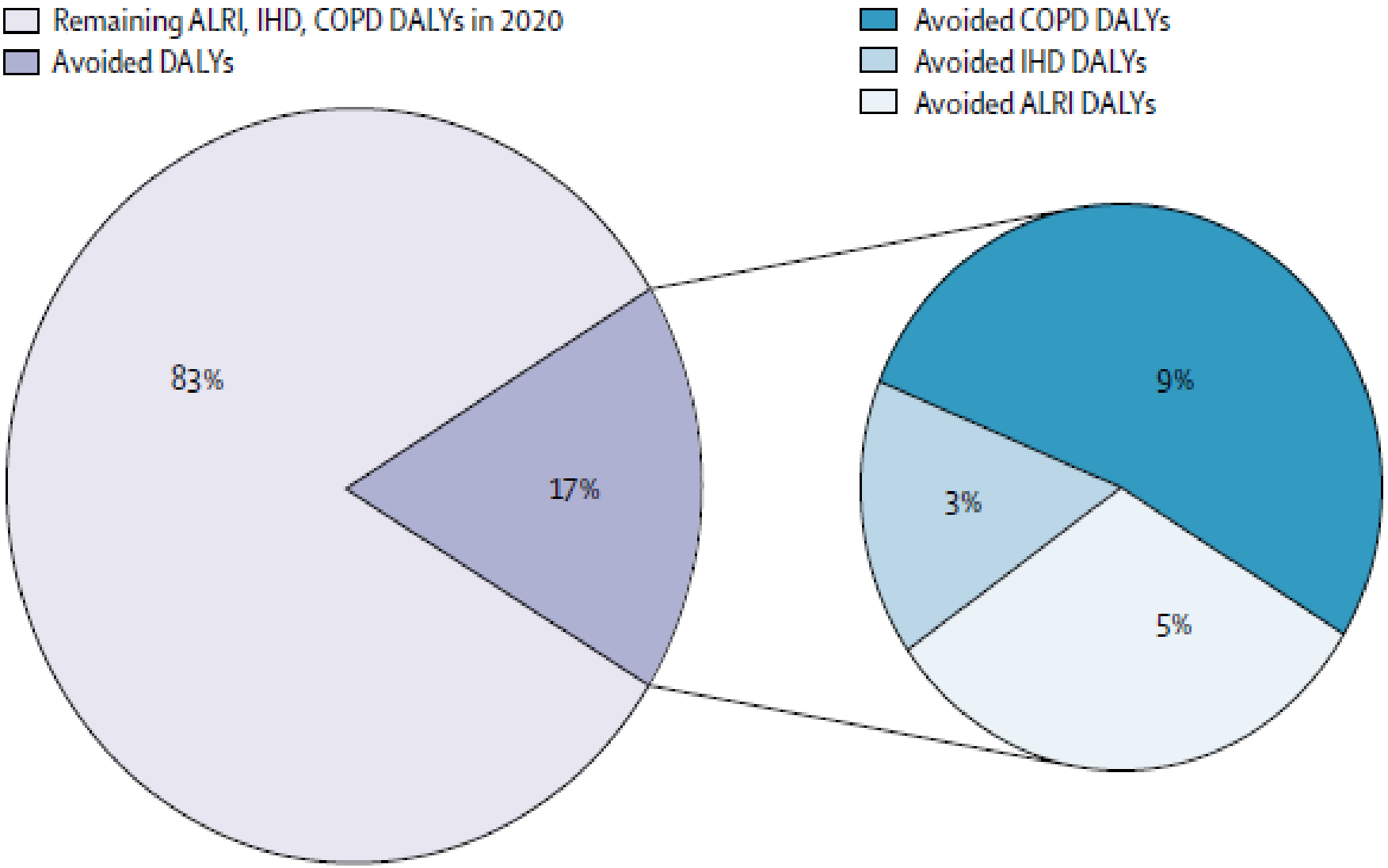
Chronic Obstructive Pulmonary Disease

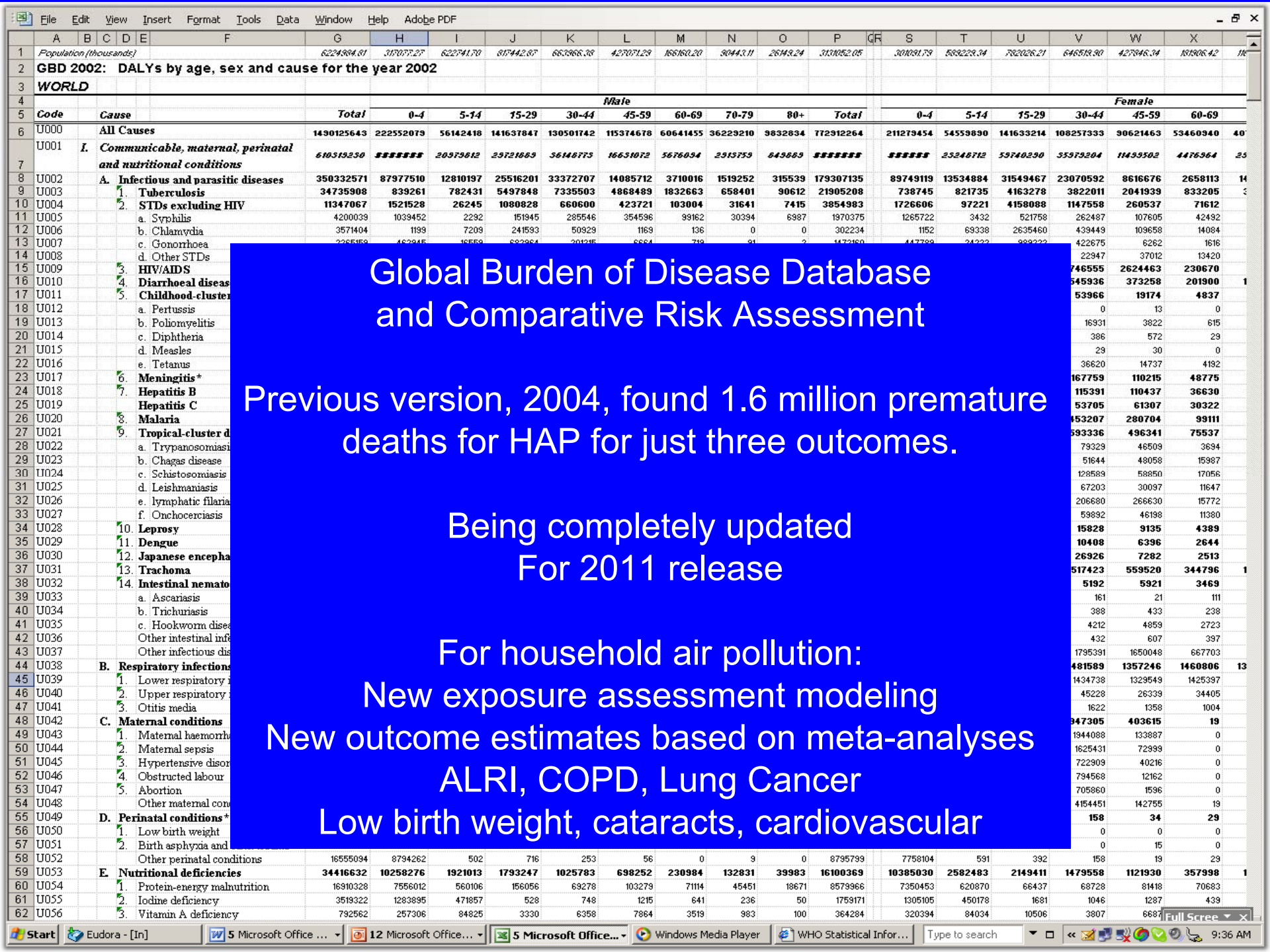
THE LANCET



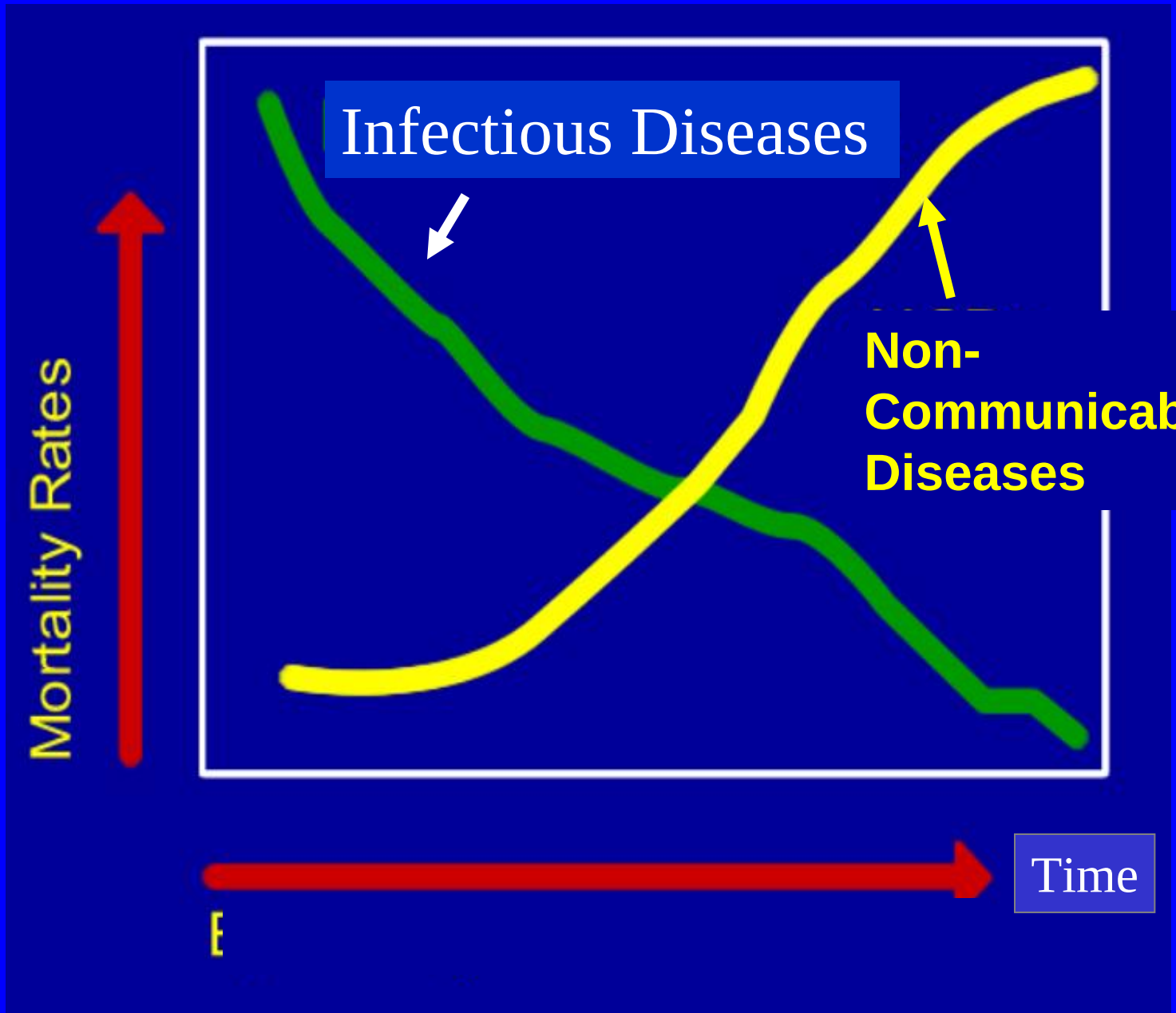
Health Benefits Upon Completion, 2020

THE LANCET




Global Burden of Disease Database
and Comparative Risk Assessment
Previous version, 2004, found 1.6 million premature deaths for HAP for just three outcomes.
Being completely updated
For 2011 release
For household air pollution:
New exposure assessment modeling
New outcome estimates based on meta-analyses
ALRI, COPD, Lung Cancer
Low birth weight, cataracts, cardiovascular

The Classic Epidemiological Transition



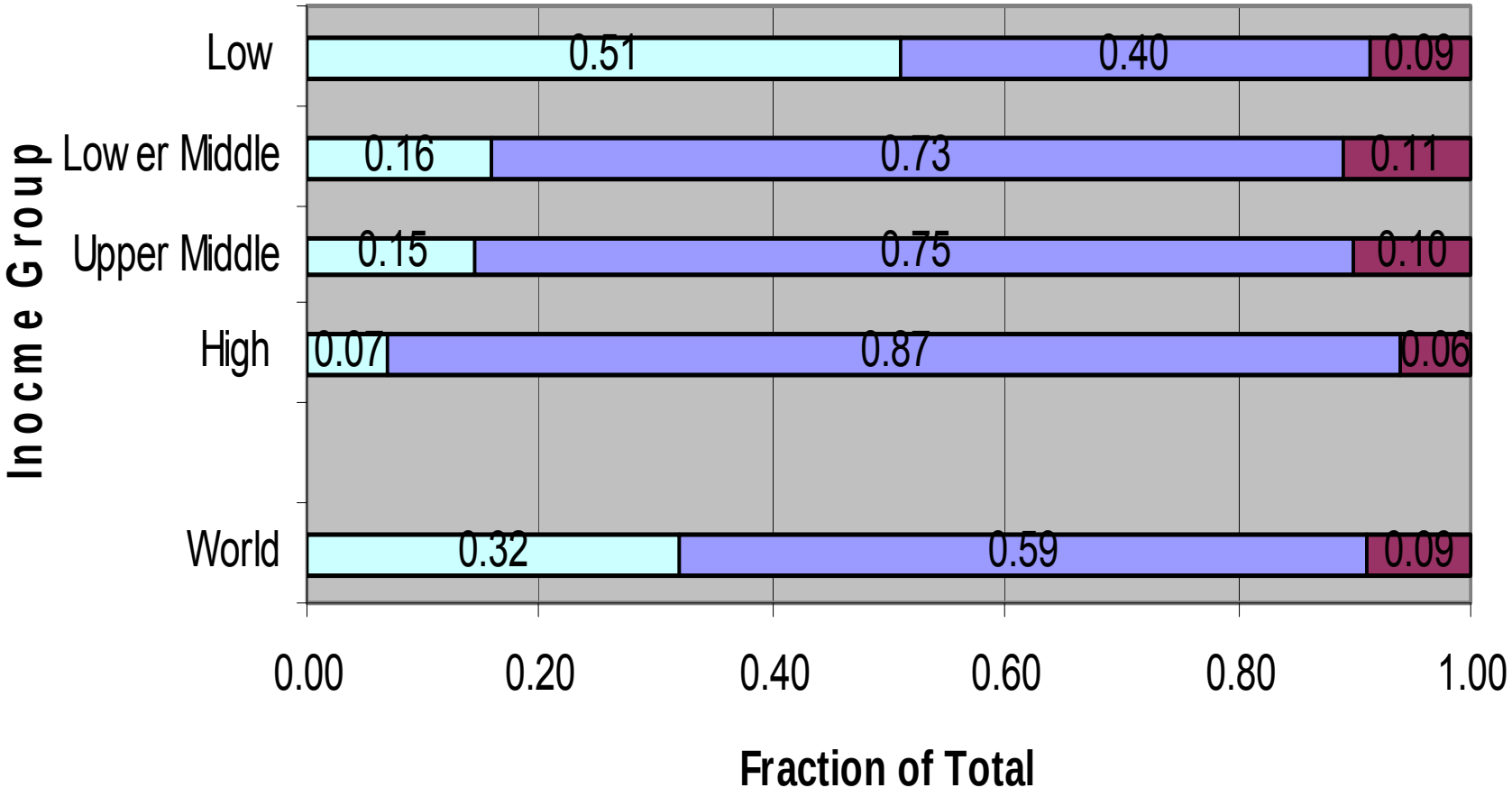
Disease Categories

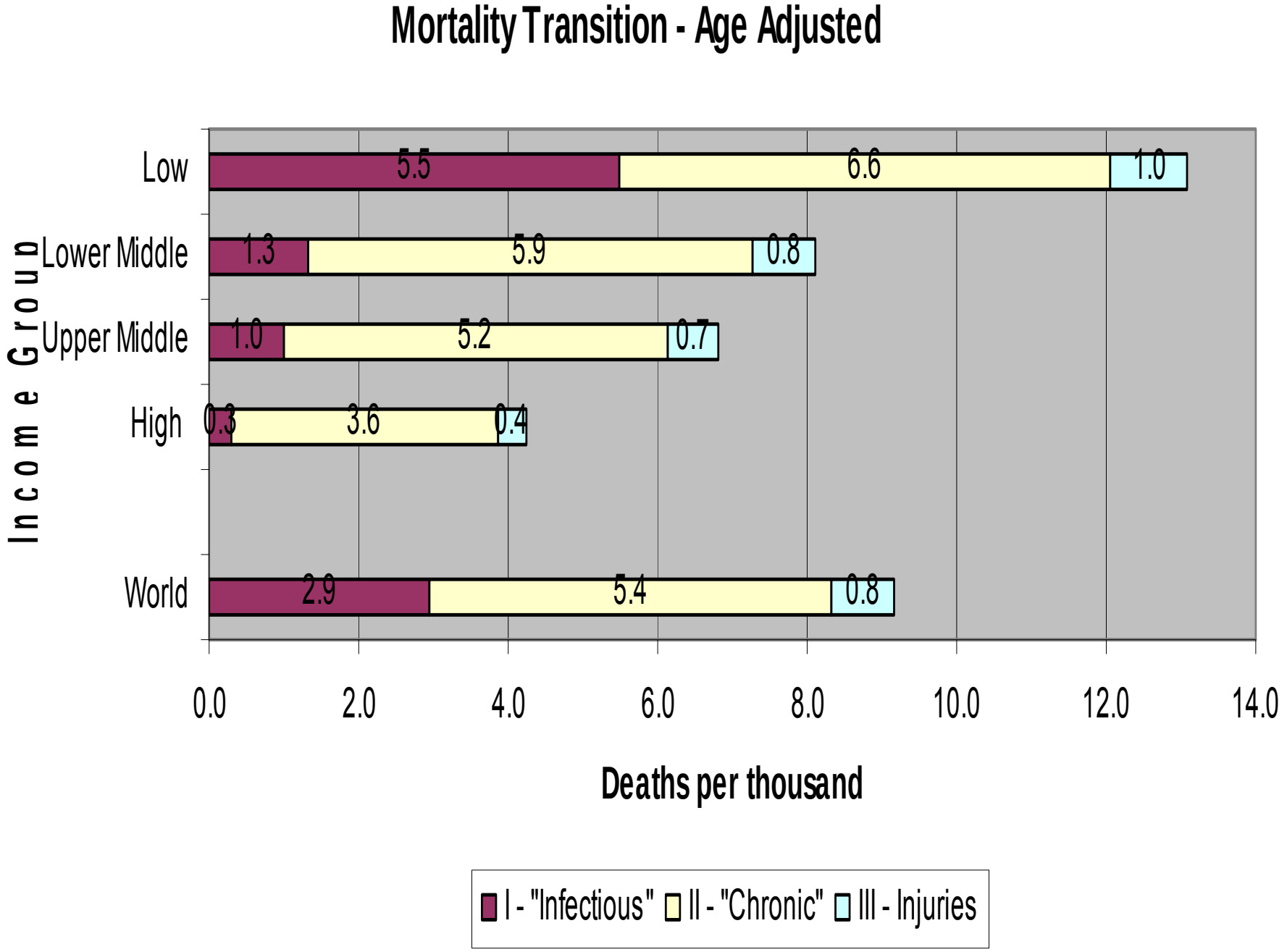
- I - Traditional, Communicable
  - Infectious, maternal, perinatal, nutritional
- II - Modern, Non-communicable
  - Cancer, heart, neuro-psychiatric, chronic lung, diabetes, congenital
- III - Injuries, Non-Transitional
  - Unintentional
    - Motor vehicle, poisoning, falls, fire, drowning
  - Intentional
    - Suicide, violence, war

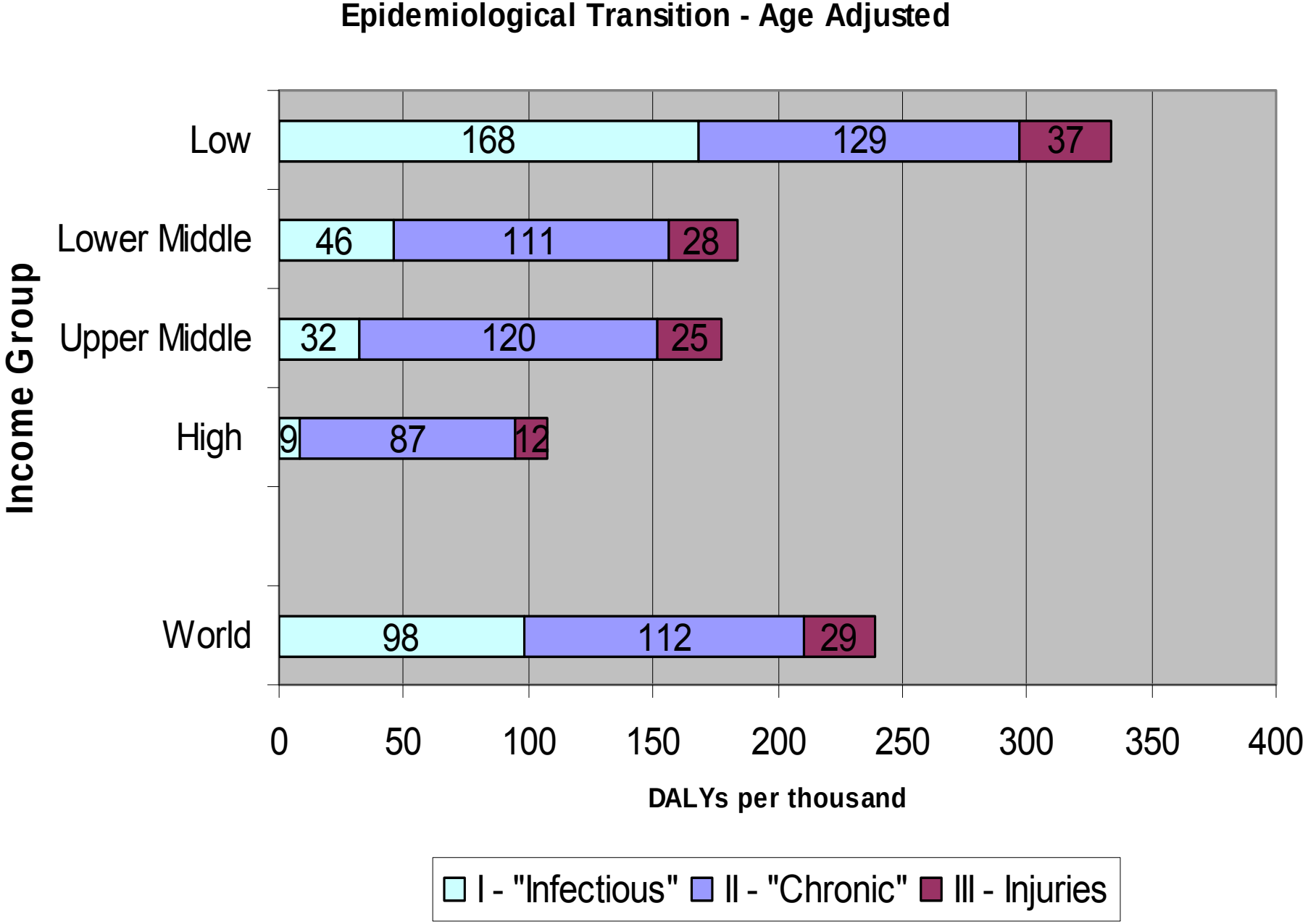
Classic Epi Transition

- I. Infectious diseases decline during development
- II. Chronic disease rise during development
- III. Injuries show no pattern during development and are thus “non-transitional”
- Test using GBD databases – only coherent global database for mortality and morbidity
- From Smith/Ezzati, 2005.

Classic Mortality Transition




Mortality Transition - Age Adjusted
Income Group
Low
Lower Middle
Upper Middle
High
World
5.5
6.6
1.0
1.3
5.9
0.8
1.0
5.2
0.7
0.3
3.6
0.4
2.9
5.4
0.8
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
Deaths per thousand
I - "Infectious"
II - "Chronic"
III - Injuries

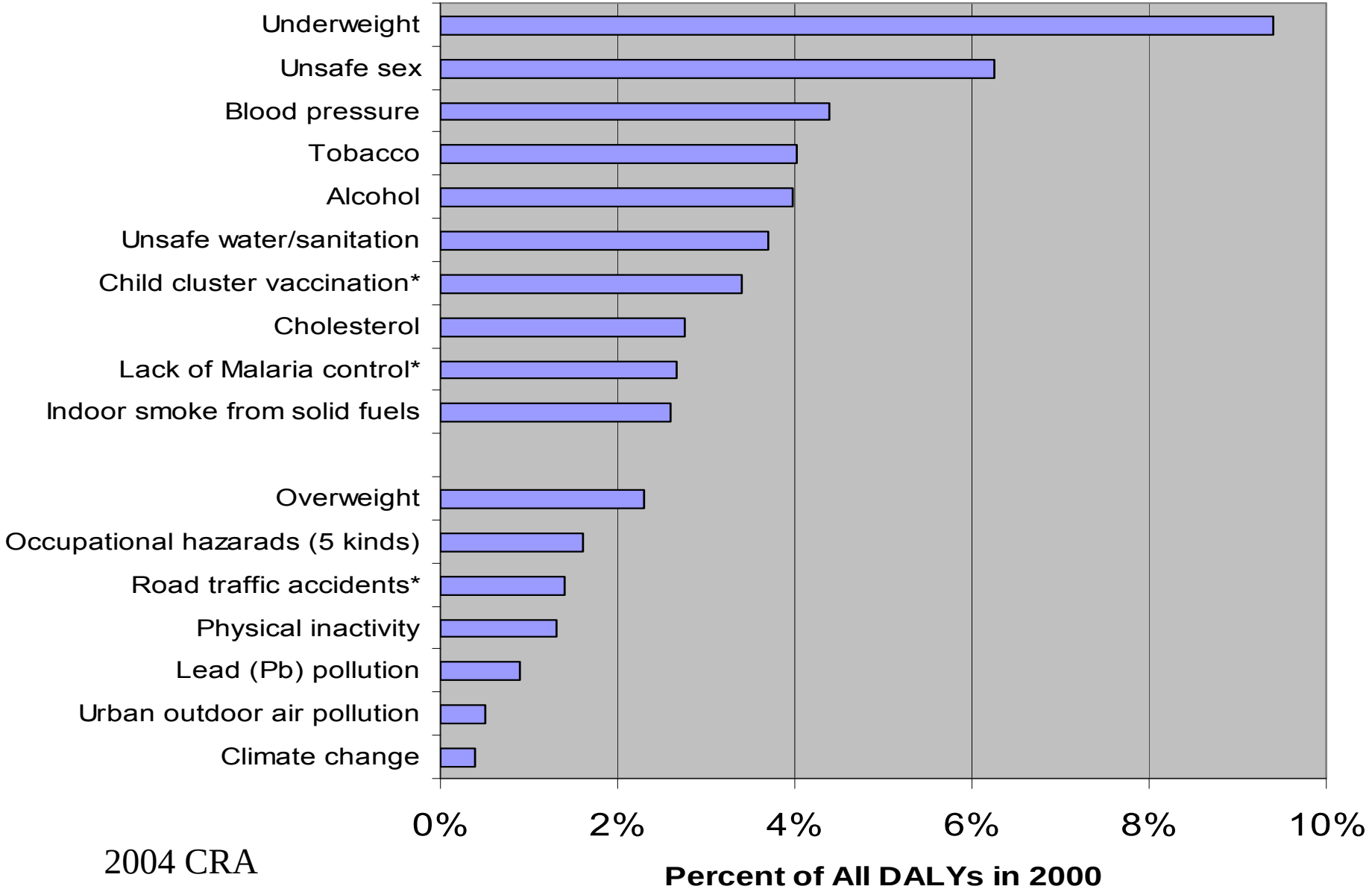

Epidemiological Transition - Age Adjusted
Income Group
Low
Lower Middle
Upper Middle
High
World
168
129
37
46
111
28
32
120
25
9
87
12
98
112
29
0
50
100
150
200
250
300
350
400
DALYs per thousand
I - "Infectious"
II - "Chronic"
III - Injuries

Epi Transition: Updated

- In terms of actual age-adjusted impact on populations, all classes of disease decline during development
  - I. Declines dramatically at every level
  - II. Declines slowly, but with little decline seen across middle income regions
  - III. Declines in a similar way to II and thus is not “non-transitional”
- Better to be rich for all major types of ill-health, although there are exceptions for individual diseases

Global Burden of Disease from Top 10 Risk Factors

plus selected other risk factors



2004 CRA

Many thanks

Publications and presentations available at my website:
http://ehs.sph.berkeley.edu/krsmith/

Or just Google “Kirk R. Smith”