

Exposure assessment

– from books to real life

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National Research Center for the Working Environment, Copenhagen



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FOR THE WORKING ENVIRONMENT

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Outline

- Exposure
 - Exposure vs. dose, agents
 - Exposure dimensions
- Exposure assessment
 - Methods of assessment
 - Exposure metrics
 - Exposure variability
- Grouping of exposure
 - Unbiased estimates
 - Job exposure matrices
 - An alternative to self-reported measurement



Why need to assess exposure

- To identify population groups with increased risks
- To quantify the relationship between exposure and adverse human health effects
- To control exposure in the workplace



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Question one

What is exposure?



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What is exposure

“The presence of a substance in the environment external to the worker” *Checkoway, Pearce, Crawford-Brown, Oxford Uni Press; 1989*

“Any contact between a substance in an environmental medium (e.g. water, air, soil) and the surface of the human body (e.g. skin, respiratory track)” *Nieuwenhuijsen Oxford Uni Press; 2003*

“Contact between an agent and a target. Contact takes place at an exposure surface at a specific point of time” *Zartarian, J Expo Anal Environ Epidemiol; 2005*



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What isn't exposure

A Dose

- Definition of dose:

- “The amount of an agent that enters a target after crossing an exposure surface” *Zartarian et al, J Expo Anal Environ Epidemiol: 2005*
- “The amount of a substance available for interaction with metabolic processes or biologically significant receptors after crossing the outer boundary of an organism” *Hayes, Principles and methods of toxicology. Taylor and Francis; 2001*



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Exposure vs. dose

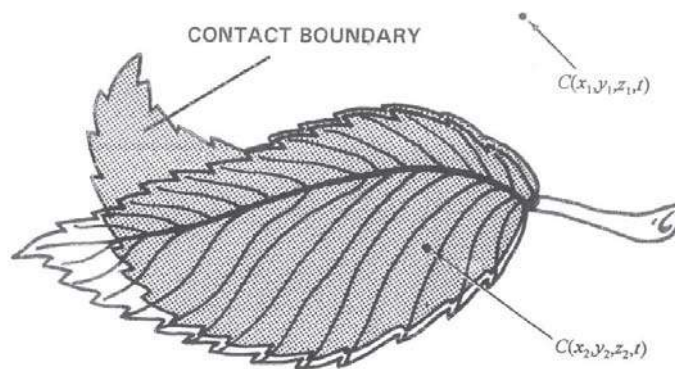


FIGURE 1. Conceptual contact boundary on the surface of a leaf. It is peeled back for illustration. The leaf is exposed to the concentration $C(x_1, y_1, z_1, t)$ at time t . It is not exposed to the concentration $C(x_2, y_2, z_2, t)$, because point 1 is not located on the leaf's contact boundary.

Zartarian, *J Expo Anal Environ Epidemiol* ;1997

Question Two

What about biomarkers?

Exposure agents

Agent is a chemical, biological, or physical entity that contacts a target”

Zartarian et al, J Expo Anal Environ Epidemiol; 2005

– Examples:

- Chemical: asbestos, benzene
- Biological: microbial dusts, endotoxin
- Physical: heat, noise, light, **mechanical forces**
- **Psychosocial: Job strain, relational justice**



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Question three

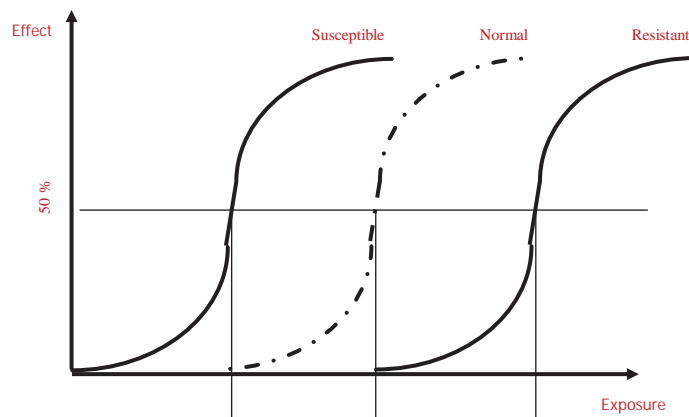
How fits the concept of exposure, agent and dose for psychosocial exposure and mechanical forces?



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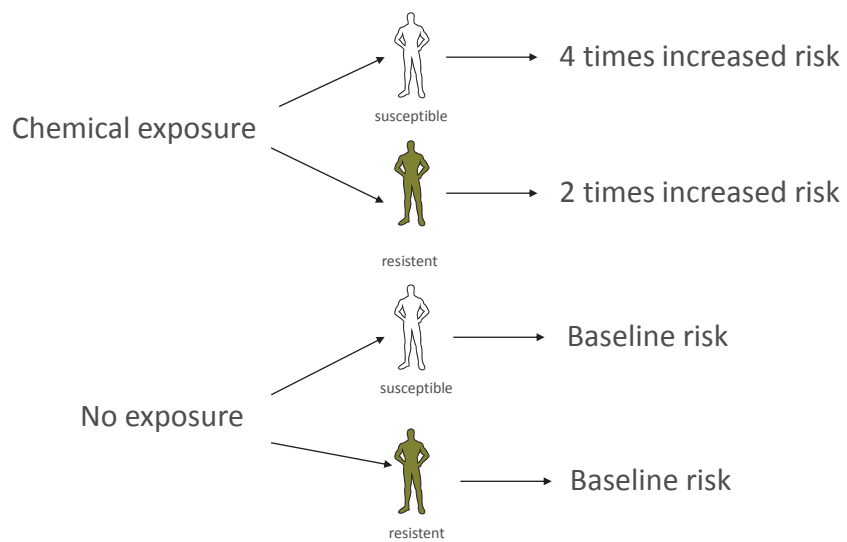
Susceptibility



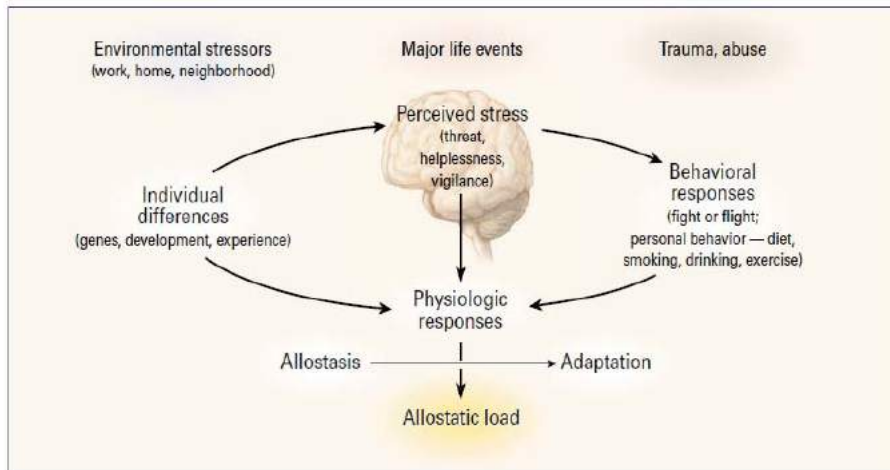
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Genetic variation in cancer metabolism



The stress model



McEwen B. N Engl J Med, 1998

How is exposure characterized

Exposure has 3 dimensions:

1. Intensity – *i.e. how much?*



2. Duration – *i.e. how long?*



3. Frequency – *i.e. how often?*



Exposure assessment

“The process of estimating or measuring the magnitude, frequency and duration of exposure to an agent along with the number and characteristics of the population involved.

Zartarian, J Expo Anal Environ Epidemiol: 2005



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Measurement instruments

Surveys

- Questionnaires
- Interviews
- Diaries

Expert opinions

Registers

Actual measurements

- Environment or worker's contact boundaries
- Blood and/or other biological specimens



Exposure models

- > Statistical/empirical
- > Deterministic
- > Job-exposure matrices

Exposure metrics

Used to estimate different summary measures (metrics) of exposure

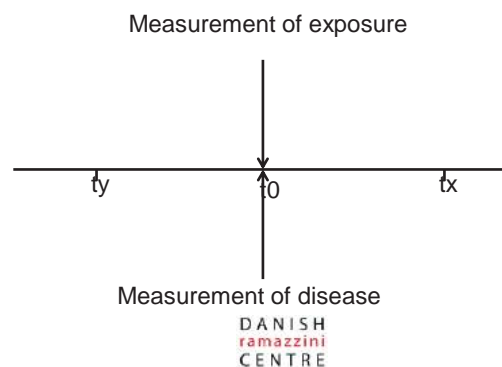


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Exposure metrics: current exposure

The concentration of exposure at the time of the investigation or at certain and short period before or after it. Usually it relates to an investigation for a health outcome



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Exposure metrics: average exposure

Arithmetic or geometric mean of exposures
(current or past)

$$\text{Mean } C = \frac{C_{\text{job1}} + C_{\text{job2}} + C_{\text{job3}} + \dots + C_{\text{jobn}}}{n}$$

$$\text{Mean } C_{\text{worker}} = \frac{C_{\text{worker1}} + C_{\text{worker2}} + C_{\text{worker3}} + \dots + C_{\text{workern}}}{n}$$



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Exposure metrics: Cumulative exposure

The summation of the concentration of exposure over
lifetime or over a specific period of time

$$\text{Cumulative exp} = \sum_i (\text{years}_i \times \text{intensity}_i)$$

$$\text{Cumulative exp} = \sum_i (\text{years}_i \times \text{frequency}_i \times \text{intensity}_i)$$

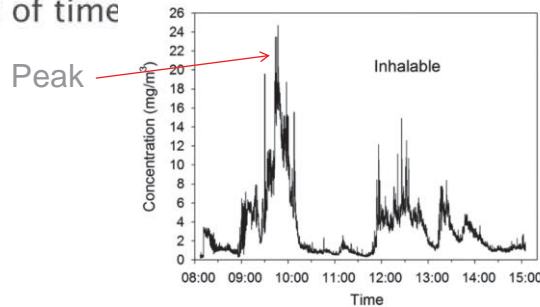


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Exposure metrics: Peak or highest exposure

Peak: the highest exposure concentration that someone is exposed to for a specific and minimum period of time



Highest: the highest concentration someone is exposed to during lifetime or over a long period of time

Figure from Freberg, Ann Occup Hyg: 2014

Question four

Discuss choice of exposure metric for:

- Job strain and acute myocardial infarction?
- Organic dust exposure and asthma ?
- Shift work and breast cancer?

Summary first hour

- Exposure and dose are not the same
- Remember the 3 exposure dimensions: duration, intensity, frequency
- The proper exposure metric depends on the suspected mechanism and the outcome



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Question four

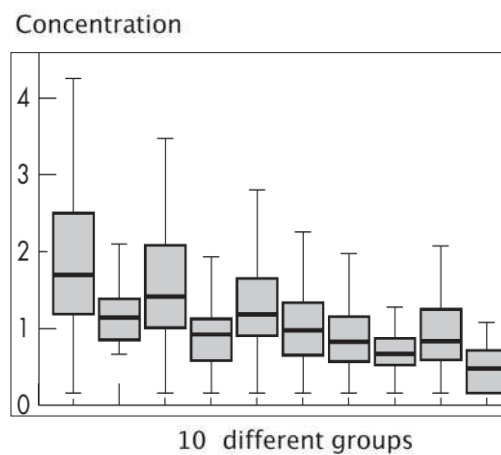
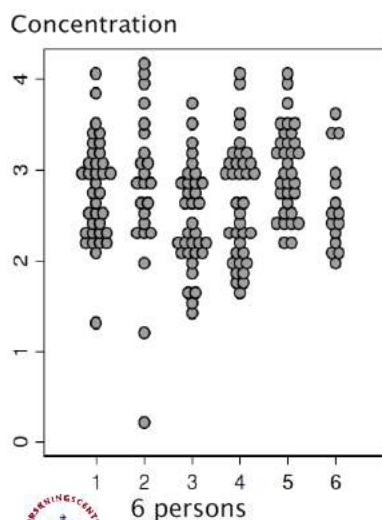
Discuss advantages and drawbacks for an individual based exposure metric and a group based exposure metric respectively



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Exposure vary!



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Variability in exposure within a day

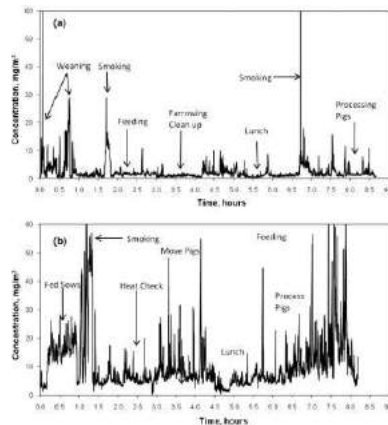


FIGURE 2. Time sequence of concentration readings for the highest case in the summer (a), and the highest case in the winter (b), showing tasks related to readings.

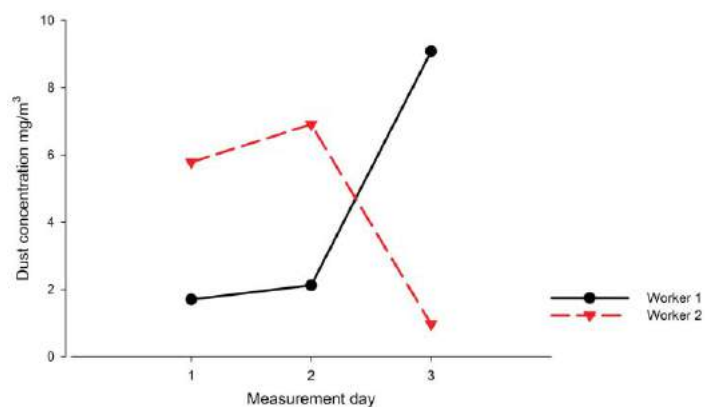
O'Shaughnessy, *J Occup Environ Hyg*: 2010



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Variability in exposure from day-to-day and between-workers among poultry farmers



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Exposure varies.....

- Within a day (within-day)
- From day-to-day (within-workers/temporal)
- Between-workers
- Between-groups of workers/factories



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Estimates of variance components, 3 x 292 dust measurement, furniture industry

		Variance	GSD
Between workers {	Within workers	0.270	1.69
	Within factories	0.215	1.59
	Between factories	0.038	1.22
	Total	0.523	2.06

Vinzens et al Ann Occup Hyg 2001



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Attenuation bias?

λ = The within- to between-worker ratio of variance

$$\beta^* = 1/(1 + \lambda/n) \times \beta \text{ (Cochran 1968)}$$

β^* = observed regression coefficient

β = true regression coefficient

n = number of observations per worker

λ = within- to between-worker ratio of variance



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Measurement errors models

Consequences for relations between exposure and health outcome

Classical error model

Measurement errors behaving according to a classical error model

introduce bias in the estimates.

Slope estimates from linear regression are attenuated towards zero.

Correction factors have been developed, but correction introduce

additional uncertainty

Berkson error model

Measurement errors behaving according to a Berkson error model **do**

not introduce bias in the estimates, but **additional uncertainty** in the estimation must be anticipated

Effect of variance on attenuation bias

	λ	% of "true" slope with 1 measurement	Number of measurements if 75% of "true" slope
Wood dust, furniture industry	1.1	48% of "true" slope	3
Dust, pig farming	3.4	23% of "true" slope	10
Endotoxin, pig farming	10	9% of "true" slope	30

λ = The within- to between-worker ratio of variance

Schlünssen et al Ann Occup Hyg 2008; Basinas et al J Environ Mon 2012



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Question five

Discuss solutions for a situation with a large within- to between-worker ratio of variance



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Solution?

- A lot of measurements!
- Calibration factor
- Grouping of subjects
- Modelling



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Cross-shift changes in FEV₁ in relation to wood dust exposure: the implications of different exposure assessment methods

V Schlünssen, T Sigsgaard, I Schaumburg, H Kromhout

Occup Environ Med 2004;61:824-830. doi: 10.1136/oem.2003.011601

Table 2 Variance components and contrast using different grouping strategies

	Number of groups	BG S_y^2	WG S_y^2	WW S_y^2	TOTAL S_y^2	Contrast
						0.300
						0.033
						0.170
						0.098
						0.228
Task + factory size	12	0.139	0.136	0.263	0.538	0.505
Task + factory	246*	0.142	0.134	0.2635	0.539	0.514
Task + factory, quintiles	5	0.204	0.115	0.263	0.582	0.639

$$\text{Contrast} = \text{BG}S_y^2 / (\text{BG}S_y^2 + \text{WG}S_y^2)$$

The result depended on the exposure metric used ...

Table 4 Adjusted linear regression on cross-shift decline in FEV₁ (the residuals adjusted for age, gender, and height) and dust exposure (1156 individuals)

RES cross-shift FEV ₁ *			
Exposure estimates	Coeff†	SE	p value
1. Individual, 1. round	0.397	0.23	0.09
2. Individual, all rounds	0.403	0.25	0.10
3. Individual, 4 groups	0.369	0.29	0.20
4. 12 categories	0.681	0.58	0.24
5. 5 categories	0.161	0.39	0.68
6. Weighted estimate	0.631	0.39	0.10
7. Mixed model 1	0.199	0.40	0.62
8. Mixed model 2	0.565	0.41	0.17

In register-based studies – Job exposure matrix

job	
1	Junior worker
2	Concrete worker
3	Carpenter apprentices
4	Carpenter
5	Carpenter
6	Teacher

Exposure levels

Exposure info in Job Exposure Matrices

- Expert judgements
- Expert judgements calibrated against measurements
- Measurements



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Important contributions from Ramazzini....

Rubak et al. *BMC Musculoskeletal Disorders* 2014, **15**:204
<http://www.biomedcentral.com/1471-2474/15/204>



RESEARCH ARTICLE

Open Access

An expert-based job exposure matrix for large scale epidemiologic studies of primary hip and knee osteoarthritis: The Lower Body JEM

Tine Steen Rubak^{1*}, Susanne Wulff Svendsen², Johan Hviid Andersen², Jens Peder Lind Haahr², Ann Kryger³, Lone Donbæk Jensen⁴ and Poul Frost⁴

Workplace



ORIGINAL ARTICLE

Cumulative occupational shoulder exposures and surgery for subacromial impingement syndrome: a nationwide Danish cohort study

Annett Dalbøge,¹ Poul Frost,¹ Johan Hviid Andersen,² Susanne Wulff Svendsen²

To cite: Dalbøge A, Frost P, Andersen JH, et al. *Occup Environ Med* 2014;**71**: 750–756.

A quantitative approach...

job	
1	Junior worker
2	Concrete worker
3	Carpenter apprentices
4	Carpenter
5	Carpenter
6	Teacher

Exposure levels
(mg/m³)/ year



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Modelling of occupational respirable crystalline silica exposure for quantitative exposure assessment in community-based case-control studies

Susan Peters,^a Roel Vermeulen,^{ab} Lützen Portengen,^a Ann Olsson,^c Benjamin Kendzia,^d Raymond Vincent,^e Barbara Savary,^e Jérôme Lavoué,^f Domenico Cavallo,^g Andrea Cattaneo,^h Dario Mirabelli,ⁱ Nils Plato,^j Joelle Fevotte,^k Beate Pesch,^d Thomas Brüning,^d Kurt Straif^c and Hans Kromhout^a

J. Environ. Monit., 2011, **13**, 3262

$$\text{Ln}(Y) = \beta_0 + \beta_t T + \beta_s S + \beta_d D + \beta_i I_{dom} + b_{j1-428} J + b_{r1-7} \text{Reg} + \varepsilon$$

Quarts Concentration Meas. year Meas. strategy Meas. time Expert assessment Job region

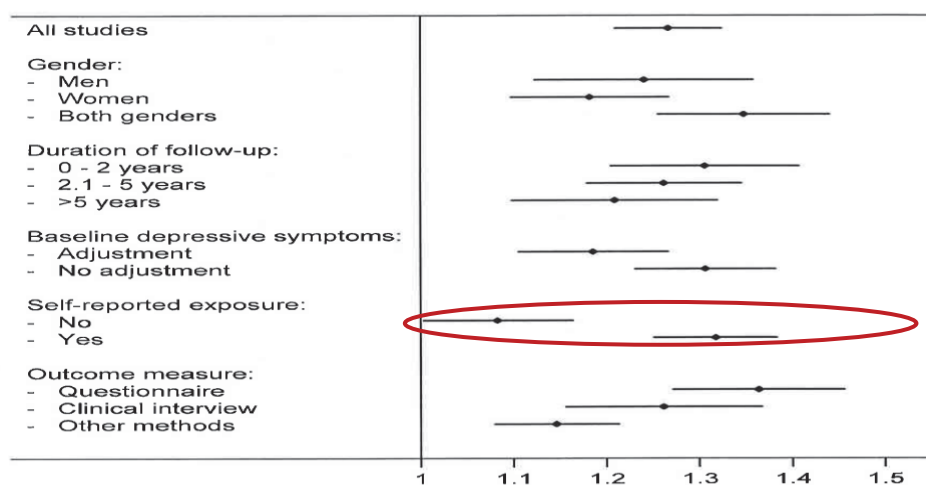
Grouping an alternative to self-reported exposure.....



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Psychosocial working environment and depression. 38 follow-up studies. Odds ratio
(Mathias Grynderup, phd thesis AU, 2013)



Measurements of psychosocial exposure groups by work unit..

Job Strain and Ischemic Heart Disease: A Prospective Study Using a New Approach for Exposure Assessment

(*J Occup Environ Med.* 2009;51:732–738)

Jens Peter Bonde, MD
Torsten Munch-Hansen, MSc
Esben Agerbo, PhD
Poul Suadicani, PhD
Joanna Wieclaw, PhD
Niels Westergaard-Nielsen, PhD

ORIGINAL ARTICLE

Work-unit measures of organisational justice and risk of depression—a 2-year cohort study

Matias Brødsgaard Grynderup,¹ Ole Mors,² Åse Marie Hansen,^{3,4}
Johan Hviid Andersen,⁵ Jens Peter Bonde,⁶ Anette Kærgaard,⁵
Linda Kærlev,⁷ Sigurd Mikkelsen,⁶ Reiner Rugulies,⁴
Jane Frølund Thomsen,⁶ Henrik Albert Kolstad¹

Grynderup MB, et al. *Occup Environ Med* 2013;**70**:380–385.

Summary second hour

- Exposure vary!
- Evaluation of attenuation bias
- Grouping



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