# WHY DO WE STILL USE JOB-EXPOSURE MATRICES?
## REFLECTIONS ON JEMS

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# Who's idea was it anyway ?

## Applications of a Job Classification System In Occupational Epidemiology

JOHN F. GAMBLE, PHD, ROBERT SPIRTAS, DRPH, AND PEGGY EASTER

AJPH August, 1976, Vol. 66, No. 8

Rationale

- grouping jobs into homogeneous categories called occupational titles (OT)
- OT not defined by exposure, but by process or function and product
- OT have complex mixtures of exposure (example rubber industry)

# Who's idea was it anyway ?

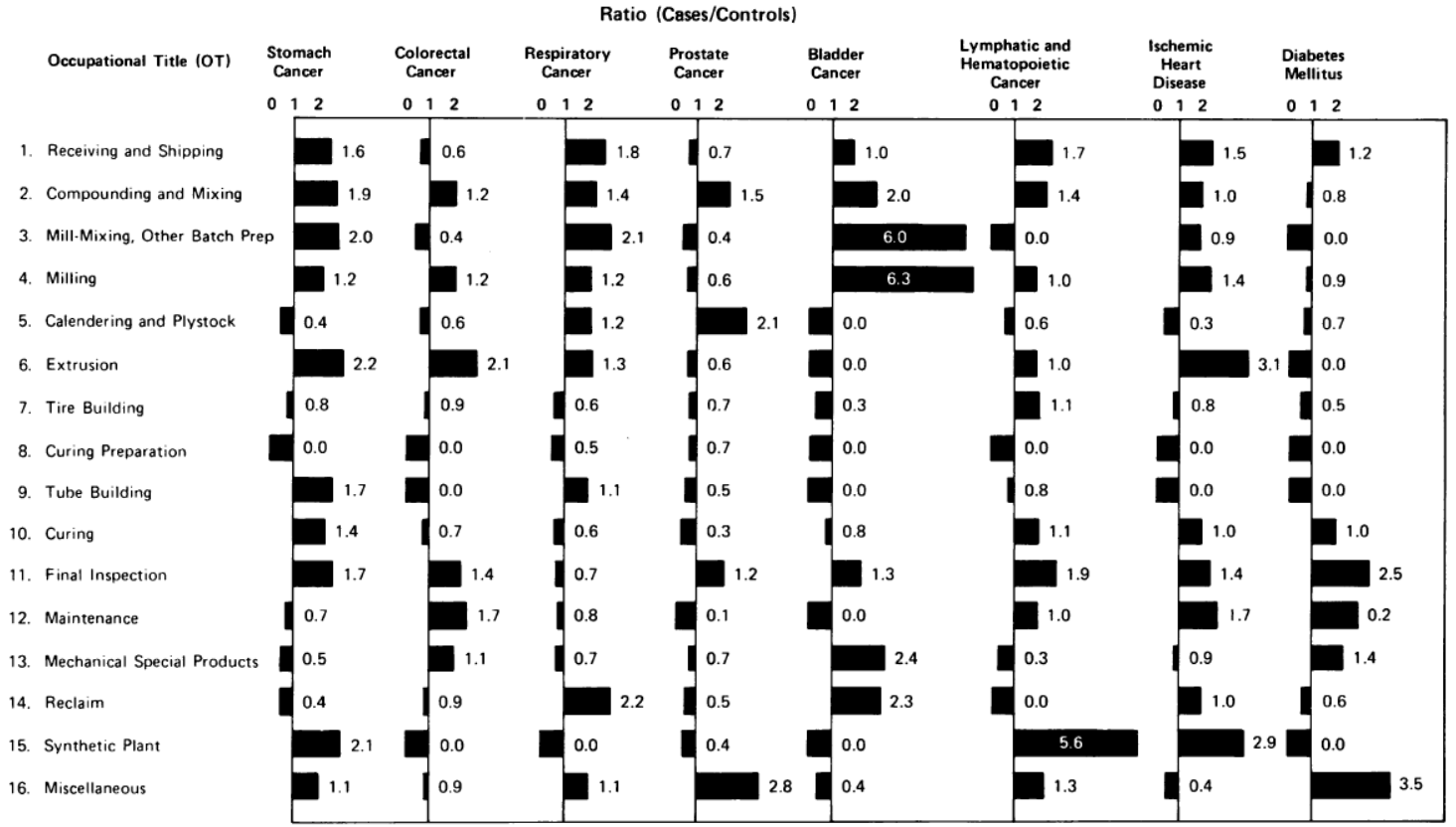


**FIGURE 2. Ratios of age-adjusted rates of exposure to specific OT's for cases compared to population sample (n = 1402). For example, 8% of stomach cases spent more than 5 years in Receiving and Shipping, versus 5% of the population sample, giving a ratio of 1.6 (from Reference 7).**

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Reflections of Gamble (1976):

- "occupational titles (OT) are used as surrogate measure of exposure patterns"
- "with increasing insight into hazards, our classification of jobs may begin to look more like categories of different exposures"
- "classification of jobs, independent of exposure, provides the essential link between environmental and medical information"

⇒ the original idea of job groups did not specify particular job-specific exposure ! (exposome *avant la lettre* !)

# Who's idea was it anyway ?

An Occupation and Exposure Linkage System for the Study of Occupational Carcinogenesis

Shelia K. Hoar, Sc.M.; Alan S. Morrison, M.D.; Philip Cole, M.D.; and Debra T. Silverman, Sc.M.

J Occup Med 1980;22:722-5. (178 citations)

A job-exposure matrix for use in population based studies in England and Wales

B PANNETT, D COGGON, AND E D ACHESON

*From the MRC Environmental Epidemiology Unit, University of Southampton, Southampton General Hospital, Southampton SO9 4XY, UK*

Br J Ind Med 1985;42:777-83. (102 citations)

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# Who's idea was it anyway ?

**TABLE 1. Main characteristics of the Medical Research Council (MRC) (3) and Harvard (2) job-exposure matrices (JEMs)**

| | Harvard JEM | MRC JEM |
|---|---|---|
| Job axis | Five digits (two digits industry code; three digits task or process code); 500 different code combinations | 669 job groups |
| Exposure axis | 334 different (groups of) agents | 50 different (groups of) agents |
| Exposure degree | 5 categories:<br>0 None<br>1 Light<br>2 Moderate<br>3 Heavy<br>9 Unknown | 4 categories:<br>0 None<br>1 Low<br>2 High<br>9 Unknown |
| Exposure evaluation | Job content<br>Hazard classification of jobs by Hueper and Conway (28) | Other JEMs<br>Textbooks of industrial hygiene, occupational medicine, toxicology, and chemistry<br>Published papers<br>Direct inquiry of trade federations |
| Job/exposure combinations | 15,000 | 33,450 |

Kromhout et al Am J Epidemiol 1992;136:698-711. (50 citations)

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**TABLE 4. Agreement (Cohen's kappa) between two job-exposure matrices for exposure to 25 agents, classified in both a lenient (A) and strict (B) manner: 1,002 jobs for 603 men in the Zutphen Study, 1977/1978**

| Agent | A* (95% CI)† | B‡ (95% CI) |
|---|---|---|
| Acrylonitrile | 0.25 (0.19–0.31) | 0.17 (0.13–0.20) |
| Aromatic amines | 0.08 (0.04–0.13) | 0.07 (0.03–0.10) |
| Arsenic | 0.16 (0.12–0.20) | —§ |
| Asbestos | 0.24 (0.18–0.30) | 0.04 (−0.02–0.10) |
| Benzene | 0.30 (0.25–0.35) | 0.11 (0.06–0.16) |
| Beryllium | 0.01 (−0.00–0.02) | —‖ |
| Cadmium | 0.10 (0.04–0.16) | —§ |
| Carbon tetrachloride | 0.29 (0.24–0.35) | −0.01 (−0.03–0.01) |
| Chlorophenol | −0.01 (−0.05–0.03) | −0.00 (−0.05–0.05) |
| Chromium | 0.44 (0.38–0.50) | −0.04 (−0.08–0.01) |
| Coal tar | 0.20 (0.14–0.27) | 0.01 (−0.05–0.07) |
| Cold | 0.55 (0.49–0.61) | 0.33 (0.28–0.38) |
| Epoxy resins | 0.07 (0.02–0.12) | —§ |
| Ethylene oxide | 0.02 (−0.04–0.07) | −0.01 (−0.04–0.03) |
| Formaldehyde | 0.01 (−0.04–0.07) | 0.07 (0.01–0.13) |
| Lead | 0.17 (0.12–0.23) | 0.03 (−0.00–0.07) |
| Mercury | 0.00 (−0.06–0.07) | —§ |
| Organic solvents | 0.11 (0.07–0.15) | 0.02 (−0.03–0.07) |
| Paints | 0.03 (0.01–0.06) | −0.01 (−0.05–0.03) |
| PCBs¶ | 0.26 (0.20–0.31) | —§ |
| Pesticides | 0.44 (0.38–0.50) | —§ |
| Styrene | 0.52 (0.46–0.58) | 0.16 (0.13–0.20) |
| Ultraviolet light | −0.01 (−0.06–0.03) | 0.10 (0.07–0.13) |
| Waxes | −0.07 (−0.13–0.00) | −0.00 (−0.02–0.01) |
| Wood dust | 0.69 (0.63–0.75) | 0.87 (0.81–0.93) |

Kromhout et al Am J Epidemiol 1992;136:698-711. (50 citations)

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# Who's idea was it anyway ?

Reflections of Hoar (1980):

- "not intended to supplant detailed industry-based exposure studies"
- useful for:
  * exploratory studies
  * situations where it is not possible to carry out more detailed exposure investigations, for example community-based studies

Reflections of Pannett (1985):

- "direct estimates from full occupational histories (case-control study) gave steeper exposure-response curves than matrix for carcinogens, but differences were small overall"
- "direct estimates offer little advantage over those provided at lower cost by a matrix"
- "grading of exposure best carried out by occupational hygienists and epidemiologists working on collaboration"

# Who's idea was it anyway ?

Reflections of Kromhout (1992):

- "self-reported exposures (e.g. asbestos) showed elevated risk ratios for lung cancer which were absent for exposures generated by the two JEMs"
- "the use of general JEMs hardly ever gives sufficiently detailed information on occupational exposures at individual level"

# Who's idea was it anyway ?

Great idea, but …better stop using it ?

# Developments in job-exposure matrices

A. Development in type of JEM:

1. General population JEM
   JEM with job codes, crude information

2. Industry-specific JEM
   JEM with more detailed job/task information

3. Population-specific JEM
   JEM linked with self-reported job history / specific exposure in particular study populations

# How well do different JEMs perform ?

ORIGINAL ARTICLE

## Comparison of expert and job-exposure matrix-based retrospective exposure assessment of occupational carcinogens in the Netherlands Cohort Study

Nadine S M Offermans,[1] Roel Vermeulen,[2,3] Alex Burdorf,[4] Susan Peters,[2] R Alexandra Goldbohm,[5] Tom Koeman,[2] Martie van Tongeren,[6] T Kauppinen,[7] Ijmert Kant,[8] Hans Kromhout,[2] Piet A van den Brandt[1]

*Occup Environ Med* 2012;**69**:745–751.

Four different JEMs:

- DOM-JEM: structured JEM based on measurements, experts
- asbestos JEM: measurements, experts
- FINJEM: measurements, experts
- Population-specific JEM, internal case-by-case assessment as golden standard

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# How well do different JEMs perform ?

Estimated exposure prevalence in each approach:

- DOM-JEM: 30.0%
- asbestos JEM: 32.9%
- FINJEM: 28.3%
- internal case-by-case evaluation: 9.3%

**Table 2** Weighted Cohen's κs and 95% CIs for cumulative exposure* assigned to the male subcohort members (N=1455) by the different methods

| | Case-by-case expert assessment versus Asbestos JEM | Case-by-case expert assessment versus DOMJEM | Case-by-case expert assessment versus FINJEM | Asbestos JEM versus DOMJEM | Asbestos JEM versus FINJEM | DOMJEM versus FINJEM |
|---|---|---|---|---|---|---|
| Asbestos | 0.10 (0.05 to 0.13) | 0.29 (0.23 to 0.32) | 0.23 (0.19 to 0.29) | 0.25 (0.20 to 0.29) | 0.42 (0.38 to 0.47) | 0.50 (0.47 to 0.55) |
| PAHs | | 0.42 (0.29 to 0.52) | 0.40 (0.32 to 0.52) | | | 0.51 (0.44 to 0.57) |
| Welding fumes | | | 0.70 (0.65 to 0.74) | | | |

*Cumulative exposure is based on P×job duration for the expert assessment and on P×I×job duration for the JEMs.
JEM, job-exposure matrice.

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# How well do different JEMs perform ?

Offermans et al. JOEM 2014

**TABLE 3.** Hazard Ratios, 95% CIs, and PAFs for Pleural Mesothelioma for Categories of Asbestos Exposure,* Estimated With DOMJEM and FINJEM in the NLCS, 1986–2003†

| | Person Years in Subcohort | Pleural Mesothelioma | | | |
|---|---|---|---|---|---|
| | | *n* | HR‡ (95% CI) | HR§ (95% CI) | PAF, % |
| *DOMJEM* | | | | | |
| Never exposed‖ | 107,557 | 66 | 1 (ref) | 1 (ref) | |
| Ever exposed‖ | 41,688 | 66 | 2.61 (1.83–3.73) | 2.62 (1.82–3.76) | 31.9 |
| Duration of exposure,¶ yrs | | | | | |
| T1 (median: 4) | 15,469 | 10 | 1.02 (0.52–2.02) | 1.03 (0.52–2.02) | |
| T2 (median: 18) | 12,615 | 26 | 3.55 (2.19–5.78) | 3.56 (2.18–5.81) | 33.1 |
| T3 (median: 37) | 13,604 | 30 | 3.67 (2.32–5.80) | 3.69 (2.31–5.87) | |
| $P_{trend}$ (over the exposed only) | | | <0.001 | <0.001 (<0.001) | |
| Continuous, per 10 yrs | 149,245 | 132 | 1.46 (1.31–1.63) | 1.46 (1.31–1.63) | |
| *FINJEM* | | | | | |
| Never exposed‖ | 112,078 | 67 | 1 (ref) | 1 (ref) | |
| Ever exposed‖ | 37,167 | 65 | 3.02 (2.11–4.32) | 3.02 (2.11–4.34) | 34.3 |
| Duration of exposure,¶ yrs | | | | | |
| T1 (median: 7) | 13,127 | 19 | 2.47 (1.45–4.21) | 2.47 (1.45–4.20) | |
| T2 (median: 25) | 11,759 | 19 | 2.88 (1.68–4.94) | 2.88 (1.67–4.95) | 34.4 |
| T3 (median: 37) | 12,281 | 27 | 3.73 (2.31–6.01) | 3.74 (2.31–6.06) | |
| $P_{trend}$ (over the exposed only) | | | <0.001 | <0.001 (0.167) | |
| Continuous, per 10 yrs | 149,245 | 132 | 1.42 (1.27–1.58) | 1.42 (1.27–1.58) | |

# Internal versus external JEM

Internal JEM:

- information on distribution of exposure within the study population
- available exposure data can be limited, hence, less precision

External JEM:

- information on distribution of exposure from external population or based upon expert judgement
- generalisability to other populations ?

# Developments in job-exposure matrices

A. Development in type of JEM

Conclusion:

- some JEMs are much better suited for general population studies, whereas other JEMs are primarily designed for industry-based populations
- JEMs with very crude, qualititative exposure information (‘the old school’) have limited value in current research
- generalisability of JEMs across populations and time is a real concern

# Developments in job-exposure matrices

B. Development in estimation of exposure:

1. Expert ratings
   JEM with job codes, crude information (e.g. low, medium, high)

2. Workers' ratings
   Workers as experts

3. Linkage of job self-reports with exposure measurements
   Job-specific questionnaires, 'calibrated' with exposure measurements

4. Linkage of expert ratings with exposure measurements
   e.g Susan Peters, Zara Stokholm, Anne Vested

# Workers' ratings in job-exposure matrices

Scand J Work Environ Health 1989;15(3):198-202

doi:10.5271/sjweh.1865

**Respiratory health of brickworkers in Cape Town, South Africa. Appropriate dust exposure indicators and permissible exposure limits.**

by Myers JE

**Table 1.** Subjective versus objective dustiness categories. (Subjdust/objdust = subjective/objective dustiness in current job, subjdust-1/objdust-1 = subjective/objective dustiness in the job prior to the current job, subjdust-2/objdust-2 = subjective/objective dustiness in the second last job)

| | Current job (subjdust versus objdust) | Previous job 1 (subjdust-1 versus objdust-1) | Previous job 2 (subjdust-2 versus objdust-2) |
|---|---|---|---|
| Consistency | 28 % | 39.4 % | 50 % |
| Bias | 54.8 % to subjective indicator | 46.5 % to subjective indicator | 33 % to subjective indicator |
| Bias score | 79.3 % to subjective indicator | 66.1 % to subjective indicator | 52.7 % to subjective indicator |
| Correlation | r = 0.09 | r = 0.08 | r = 0.22 |

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# Workers' ratings in job-exposure matrices

**Relationship of Respiratory Health Status to Grain Dust in a Witwatersrand Grain Mill: Comparison of Workers' Exposure Assessments With Industrial Hygiene Survey Findings**

S. Fonn, MBBCh PhD, H.T. Groeneveld, DSc, M. deBeer, BSc, and M.R. Becklake, MD

American Journal of Industrial Medicine 24:401–411 (1993)

Cohen's kappa = 0.09

Workers overestimated their exposure

**TABLE I. Number of Workers by Subjective and Objective Dust Categories in a Grain Mill***

| Objective dust category | Subjective dust category | | | | |
|---|---|---|---|---|---|
| | Very high | High | Medium | Low | Total |
| Very high | 23 | 6 | 1 | 0 | 30 |
| High | 56 | 21 | 10 | 4 | 91 |
| Medium | 22 | 5 | 5 | 1 | 33 |
| Low | 25 | 40 | 53 | 33 | 151 |
| Total | 126 | 72 | 69 | 38 | 305 |

*Agreement between subjective and objective dust categories was assessed as follows: Kendall's tau-b = 0.448, chi square = 90.45, p = 0.00, contingency coefficient = 0.478.

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# Linkage self-reports and measurements

3. Linkage of job self-reports with exposure measurements
   Job-specific questionnaires, ‘calibrated’ with exposure measurements

Example in study on occupational risk factors for semen quality:

- general questionnaire with job history, then job-specific questionnaire
- 218 subjects delivered urine sample at end of the workday
- 100 out of 218 subjects wore a passive diffusion monitor

*Occup Environ Med* 1999;**56**:145–151



## Assessment of occupational exposures in a general population: comparison of different methods

Erik Tielemans, Dick Heederik, Alex Burdorf, Roel Vermeulen, Hendrik Veulemans, Hans Kromhout, Karin Hartog

# Linkage self-reports and measurements

3. Linkage of self-reports with exposure measurements

   Job-specific questionnaires, 'calibrated' with exposure measurements

*Table 2 Concentrations of volatile organic compounds ($mg/m^3$) for various organic solvent exposure groups as assessed by job specific questionnaires*

| *Exposure group* | *N* | *Median* | *Range* |
|---|---|---|---|
| High | 26 | 60*** | 1–2673 |
| Solvent based paint | 10 | 46 | 3–154 |
| Solvent based glue | 6 | 448 | 2–2673 |
| Printing ink | 8 | 33 | 1–179 |
| Miscellaneous* | 2 | 20 | 8–33 |
| Moderate | 36 | 3** | 0–160 |
| Paint or glue | 7 | 2 | 1–10 |
| Degreasers or cleaning products | 3 | 5 | 2–8 |
| Laboratory solvents | 9 | 2 | 0–5 |
| Miscellaneous† | 17 | 5 | 0–160 |
| Low or none | 27 | 1 | 0–26 |

*Table 4 Concentrations of urinary chromium for various groups exposed to amounts of chromium as assessed by job specific questionnaires, and a group of subjects initially classified as not exposed according to the generic questionnaires*

| | *U-Cr concentrations (µg/g creatinine)* | | | |
|---|---|---|---|---|
| *Exposure group* | *n* | *GM* | *GSD* | *U-Cr≥5* |
| High† | 19 | 2.3*** | 2.1 | 3 |
| Moderate† | 15 | 1.3 | 1.8 | 1 |
| Low or none† | 102 | 1.4 | 1.9 | 0 |
| Initially classified as not exposed | 20 | 1.2 | 1.8 | 0 |

Cohen's kappa = 0.08 with self-reports

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# Developments in job-exposure matrices

B. Development in estimation of exposure

Conclusion:

- workers are probably not a good source for estimation of level of exposure (dust, chemical exposure)…but…still common for physical and psychosocial factors
- enrichment of expert ratings with objective exposure assessment is an interesting development:
  * provide experts with exposure information to calibrate their ratings
  * Bayesian approach: expert ratings as priors
    ($\Rightarrow$ lecture of Susan Peters)

# Developments in job-exposure matrices

C. Development in job classification:

1. Job classification within industry classification (old system)
   Level of grouping is an important issue

2. Job classification based on education and training (current system)
   Better for some exposures, worse for others

# Job classification in job-exposure matrices

Coding systems:

- current classification; education, job, activities, competencies
  first digit = 5 classes, 3 digits = job group, 5 digits = job title
- old classification; jobs within specific industries
  2 digits = branch of industry, 4 digits = job title

Problems:

* current classification: very useful for education-related exposures (e.g. psychosocial factors), but job titles with completely different exposure profiles into similar codes
* old classification: not useful for modern jobs (e.g ICT is completely lacking) or jobs with strong development (eg order picker in warehouse)
* do not underestimate inter-observer agreement !

# Job classification in job-exposure matrices

Study population (n > 3000) with 37 OJT (each at least 30 subjects) - new system

| Mechanical load | prevalence | explained variance by 5 digits OJT |
|---|---|---|
| sitting | 50% | 38% |
| standing | 23% | 28% |
| walking | 18% | 18% |
| mmh > 5 kg | 14% | 12% |
| mmh > 25 kg | 2.1% | 7.8% |
| driving > 4 hrs | 1.4% | 2.9% |

# Job classification in job-exposure matrices

Study population with 17 occupational job groups, comparable OJT (n=37) collated (structure in taxonomy, 5 digits OJT into 3 digit OTG)

| Physical load | explained variance by OJT | by OTG |
|---|---|---|
| sitting | 38% | 27% |
| standing | 28% | 14% |
| walking | 18% | 11% |
| mmh > 5 kg | 12% | 8.1% |
| mmh > 25 kg | 7.8% | 7.0% |
| driving > 4 hrs | 2.9% | 1.3% |

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# Job classification in job-exposure matrices

Development of formal job description systems (O*NET online)

O*NET OnLine

**Summary Report for:**
47-2181.00 - Roofers

International expert based system, enriched with survey information from US population surveys

Dale et al OEM 2018;75:501-6
Huntley et al AJIM 2017;60:518-28
Grzywacz et al JOEM 2016;58:535-41

**Work Context**

All 38 displayed

- **Outdoors, Exposed to Weather** — 98% responded "Every day."
- **Exposed to High Places** — 90% responded "Every day."
- **Face-to-Face Discussions** — 70% responded "Every day."
- **Telephone** — 57% responded "Every day."
- **Contact With Others** — 56% responded "Constant contact with others."
- **Wear Common Protective or Safety Equipment such as Safety Shoes, Glasses, Gloves, Hearing Protection, Hard Hats, or Life Jackets** — 54% responded "Every day."
- **Exposed to Contaminants** — 65% responded "Every day."
- **Importance of Being Exact or Accurate** — 54% responded "Very important."
- **Responsible for Others' Health and Safety** — 58% responded "High responsibility."
- **Time Pressure** — 41% responded "Once a week or more but not every day."
- **Very Hot or Cold Temperatures** — 48% responded "Once a week or more but not every day."
- **Work With Work Group or Team** — 57% responded "Extremely important."
- **Sounds, Noise Levels Are Distracting or Uncomfortable** — 47% responded "Every day."
- **Physical Proximity** — 54% responded "Moderately close (at arm's length)."
- **Spend Time Using Your Hands to Handle, Control, or Feel Objects, Tools, or Controls** — 41% responded "Continually or almost continually."
- **Level of Competition** — 39% responded "Highly competitive."

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# Developments in job-exposure matrices

C. Development in job classification:

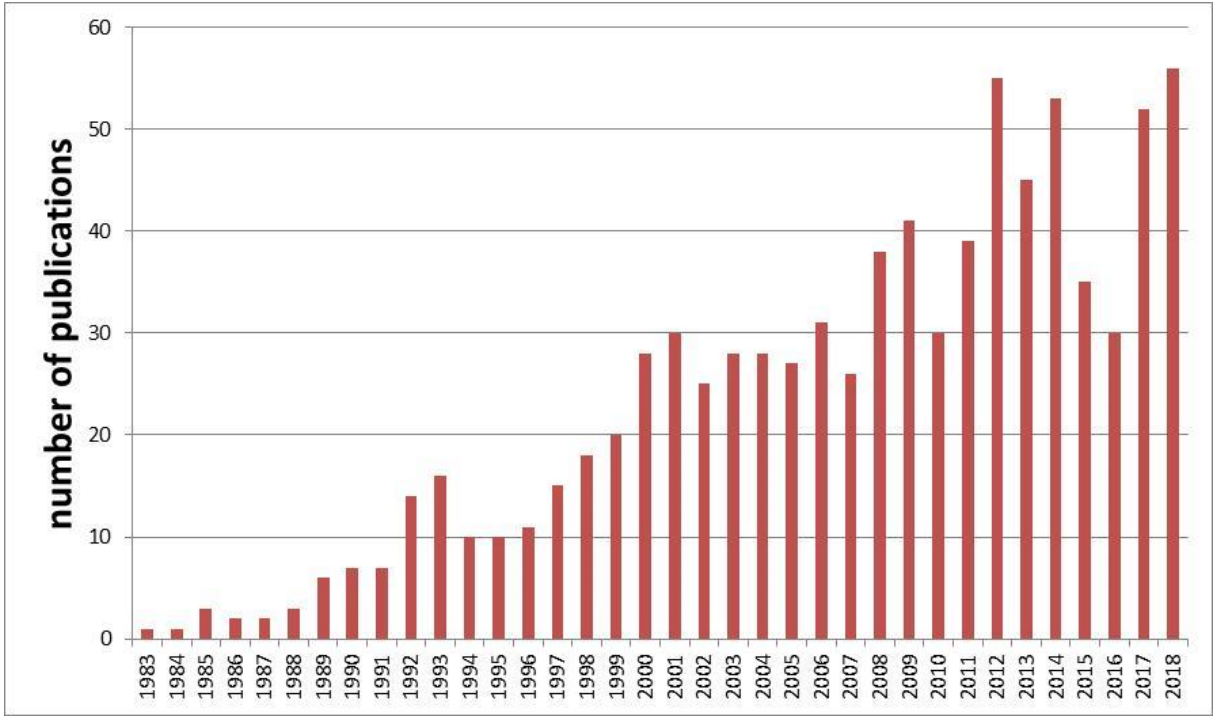
Conclusion:

- JEM performance partly determined by between-worker (=within-group) and between-job variance, post hoc evaluation needed to determine optimum grouping strategy
  (⇒ lecture of Esben Budtz-Jørgensen)
- how specific should the Occupational Job Title be ?
  5 digit level requires more information for appropriate classification
- standardized job descriptions may guide exposure assessment

# Why do we still use job-exposure matrices ?

# Why do we still use job-exposure matrices ?

1. Because we can !

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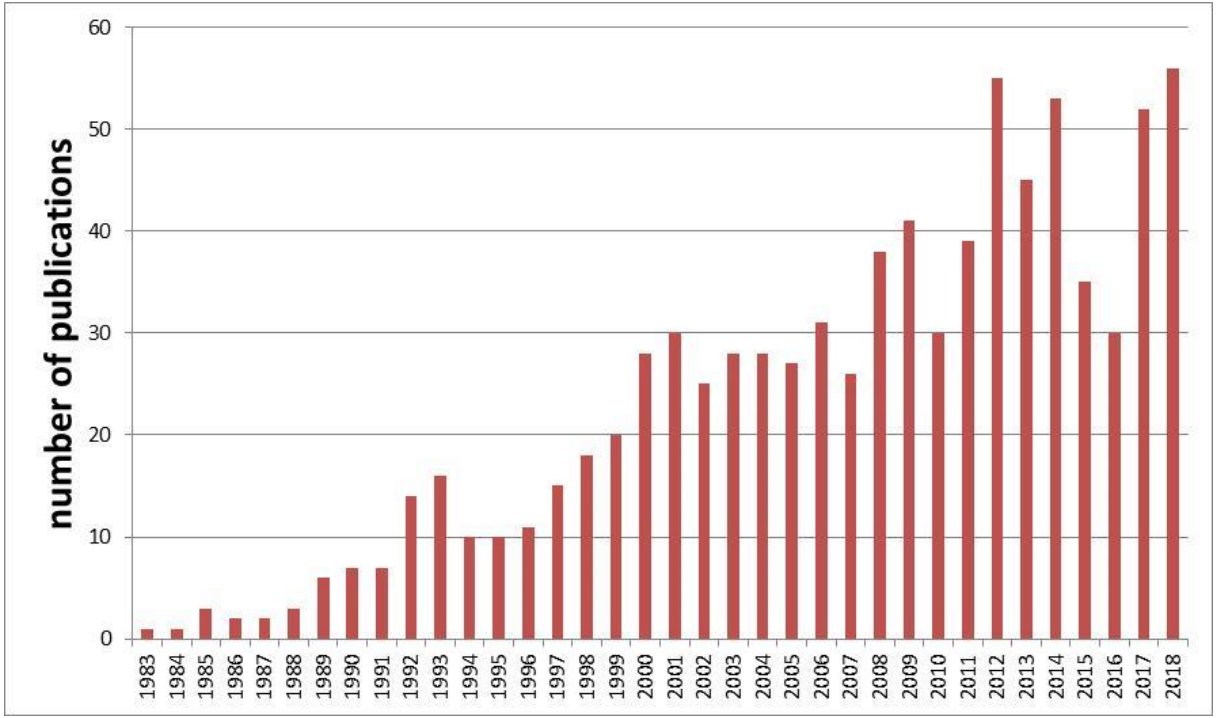
# Why do we still use job-exposure matrices ?

1. Because we can !




Correlation coefficient
= 0.94

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# Why do we still use job-exposure matrices ?

2. Because it adds information !

**TABLE 4. Regression analysis of the relation between average exposure to coal dust and 11-year change of lung function ($FEV_1$) for 1,172 coal miners, corrected for age, standing height, and pack-years of tobacco smoked for different exposure assessment strategies, and estimated average cumulative exposure and standard deviation (mg x year/m³), National Study of Coal Workers' Pneumoconiosis, 1969–1981**

| | $FEV_1$ coefficient (ml per mg/m³) | SE* (ml per mg/m³) | Correlation† | Average exposure | SD* |
|---|---|---|---|---|---|
| Individual | –4.4 | 1.6 | 1.0 | 10.4 | 7.4 |
| Six categories | –2.2 | 3.2 | 0.39 | 10.0 | 3.9 |
| Six categories + time (10)‡ | –3.2 | 3.4 | 0.39 | 10.3 | 3.8 |
| Six categories + time (4) | –2.0 | 3.1 | 0.39 | 10.4 | 3.9 |
| Six categories + mine | –5.9 | 2.4 | 0.53 | 10.0 | 5.2 |
| Model category + mine | –5.0 | 1.9 | 0.51 | 10.0 | 4.9 |
| External matrix | –2.0 | 2.4 | 0.47 | 10.2 | 5.0 |

* SE, standard error of the regression coefficient; SD, standard deviation.
† Pearson's correlation between average individual exposures using all exposure measurements and the exposure generated with a particular grouping strategy.
‡ Numbers in parentheses, number of categories.

Heederik et al. Am J Epidemiol 2000;151:982-90

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# Why do we still use job-exposure matrices ?

3. Because there is no alternative !

## *Original article*

Scand J Work Environ Health Online-first -article

doi:10.5271/sjweh.3757

**Occupational biomechanical risk factors for surgically treated ulnar nerve entrapment in a prospective study of male construction workers**

by Jackson JA, Olsson D, Punnett L, Burdorf A, Järvholm B, Wahlström J

# Some (classical) considerations

Usefulness of a job-exposure matrix:

- sufficient detail of exposure characterisation:
  * too crude will no longer do
  * linkage of exposure assessment with other information is the future

- carefully consider JEM performance relative to exposure prevalence:
  * low prevalence, specificity is more important
  * high prevalence, sensitivity becomes more important

- different JEMs for different study populations (community, industry etc)

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