Composite variable models in occupational stress research

- a critical review of the job strain and effort–reward imbalance theories of occupational stress

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Job strain and heart disease

Job strain as a risk factor for coronary heart disease: a collaborative meta-analysis of individual participant data

Mika Kivimäki, Solja T Nyberg, G David Batty, Eleonor I Fransson, Katriina Heikkilä, Lars Alfredsson, Jakob B Bjorner, Marianne Borritz, Hermann Burr, Annalisa Casini, Els Clays, Dirk De Bacquer, Nico Dragano, Jane E Ferrie, Goedele A Geuskens, Marcel Goldberg, Mark Hamer, Wendela E Hooftman, Irene L Houtman, Matti Joensuu, Markus Jokela, France Kittel, Anders Knutsson, Markku Koskenvuo, Aki Koskinen, Anne Kouvonen, Meena Kumari, Ida E H Madsen, Michael G Marmot, Martin L Nielsen, Maria Nordin, Tuula Oksanen, Jaana Pentti, Reiner Rugulies, Paula Salo, Johannes Siegrist, Archana Singh-Manoux, Sakari B Suominen, Ari Väänänen, Jussi Vahtera, Marianna Virtanen, Peter J M Westerholm, Hugo Westerlund, Marie Zins, Andrew Steptoe, Töres Theorell, for the IPD-Work Consortium

Summary

Background Published work assessing psychosocial stress (job strain) as a risk factor for coronary heart disease is inconsistent and subject to publication bias and reverse causation bias. We analysed the relation between job strain and coronary heart disease with a meta-analysis of published and unpublished studies.

Methods We used individual records from 13 European cohort studies (1985–2006) of men and women without coronary heart disease who were employed at time of baseline assessment. We measured job strain with questions from validated job-content and demand-control questionnaires. We extracted data in two stages such that acquisition and harmonisation of job strain measure and covariables occurred before linkage to records for coronary heart disease. We defined incident coronary heart disease as the first non-fatal myocardial infarction or coronary death.

Findings 30 214 (15%) of 197 473 participants reported job strain. In 1·49 million person-years at risk (mean follow-up 7·5 years [SD 1·7]), we recorded 2358 events of incident coronary heart disease. After adjustment for sex and age, the hazard ratio for job strain versus no job strain was 1·23 (95% CI 1·10–1·37). This effect estimate was higher in published (1·43, 1·15–1·77) than unpublished (1·16, 1·02–1·32) studies. Hazard ratios were likewise raised in analyses addressing reverse causality by exclusion of events of coronary heart disease that occurred in the first 3 years (1·31, 1·15–1·48) and 5 years (1·30, 1·13–1·50) of follow-up. We noted an association between job strain and coronary heart disease for sex, age groups, socioeconomic strata, and region, and after adjustments for socioeconomic status, and lifestyle and conventional risk factors. The population attributable risk for job strain was 3·4%.

Lancet 2012; 380: 1491–97

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See Comment page 1455

Department of Epidemiology and Public Health, University College London, London, UK (Prof M Kivimäki PhD, G D Batty PhD, J E Ferrie PhD, M Hamer PhD, M Kumari PhD, Prof M G Marmot MD, A Singh-Manoux PhD, Prof A Steptoe DPh); Institute of Behavioral Sciences, University of Helsinki, Helsinki, Finland (Prof M Kivimäki, M Jokela PhD); Finnish Institute of Occupational Health, Helsinki, Finland (Prof M Kivimäki, S T Nyberg MSc, K Heikkilä PhD,

(Kivimäki et al, *Lancet*, 2012)

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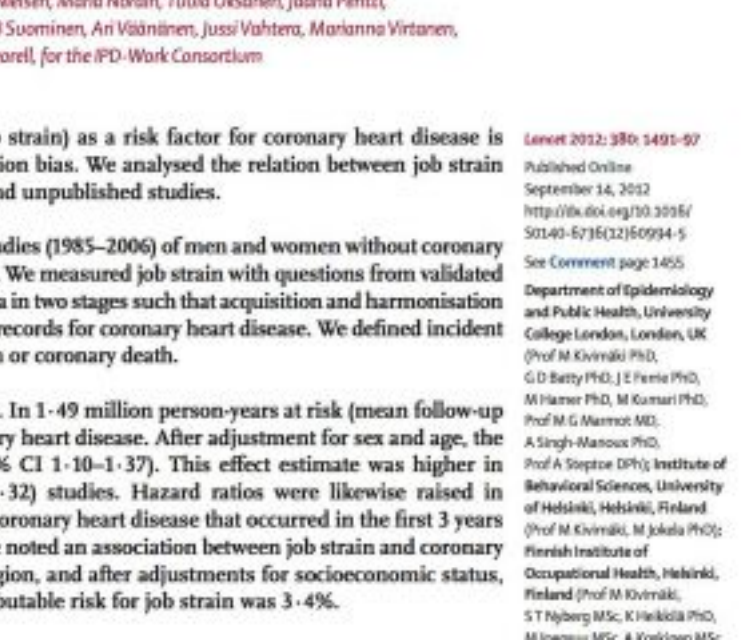

Jussi Suominen, Ari Väänänen, Jussi Vahtera, Marianna Virtanen,
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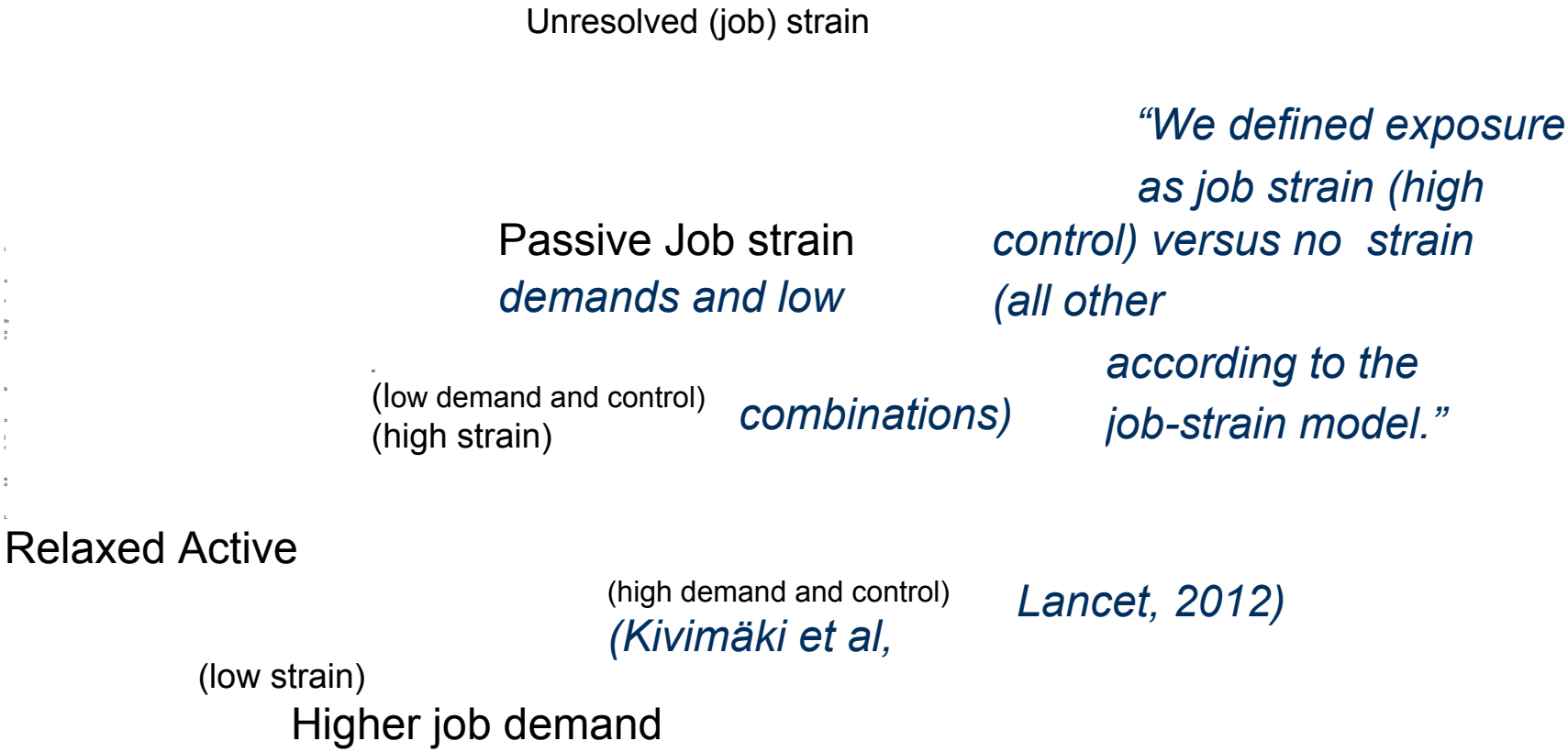
The job strain model



Adapted from figure 1 in Karasek (1979) (Michael Ingre, *Doctoral thesis*, 2017)

… is a similar problem as the effort–reward imbalance model (ERI)

Unresolved (job) strain

imbalance

Low effort and reward

ERI

Passive Job strain

(effort = reward)
Effort–reward

(effort > reward)

(low demand and control)
(high strain)

Low effort and

High effort and

high reward (reward > effort)

reward

Relaxed Active

(effort = reward)

(low strain)

control)

(high demand and

Higher perceived effort

Higher job demand

Job control and reward, but NOT job demand and effort, are associated with CHD!

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Effort–Reward Imbalance at Work and Incident Coronary Heart Disease

A Multicohort Study of 90,164 Individuals

Nico Dragano,[a] Johannes Siegrist,[a] Solja T. Nyberg,[b] Thorsten Lunau,[a] Eleonor I. Fransson,[c,d,e] Lars Alfredsson,[c,f] Jakob B. Bjorner,[g] Marianne Borritz,[h] Hermann Burr,[i] Raimund Erbel,[j] Göran Fahlén,[k] Marcel Goldberg,[l,m] Mark Hamer,[n,o] Katriina Heikkilä,[p,q] Karl-Heinz Jöckel,[j] Anders Knutsson,[r] Ida E. H. Madsen,[g] Martin L. Nielsen,[s] Maria Nordin,[e,t] Tuula Oksanen,[u] Jan H. Pejtersen,[v] Jaana Pentti,[w] Reiner Rugulies,[g,x] Paula Salo,[y,z] Jürgen Schupp,[r] Archana Singh-Manoux,[l] Andrew Steptoe,[n] Töres Theorell,[e] Jussi Vahtera,[y,aa] Peter J. M. Westerholm,[bb] Hugo Westerlund,[e] Marianna Virtanen,[y] Marie Zins,[l,m] G. David Batty,[c] and Mika Kivimäki,[b,n,o] for the IPD-Work consortium

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We are unable to provide direct access to the data from the single studies analyzed here. Code is available on request.

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In analysis of the components of effort–reward imbalance, the age- and sex-adjusted hazard ratio of incident coronary heart disease was 0.99 (95% CI = 0.87, 1.13) for high (above median) versus low (median or below) efforts and 1.18 (95% CI = 1.04, 1.33) for low (below median) versus high (median or higher) rewards.

ORIGINAL ARTICLE

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The Gin Tonic Model

Job strain and the Gin

Passive Job strain

Tonic model Unresolved (job) strain

Intoxication

(low demand and control)
(high strain)

Nothing

Relaxed Active (high demand and control)

(low strain)

More Tonic

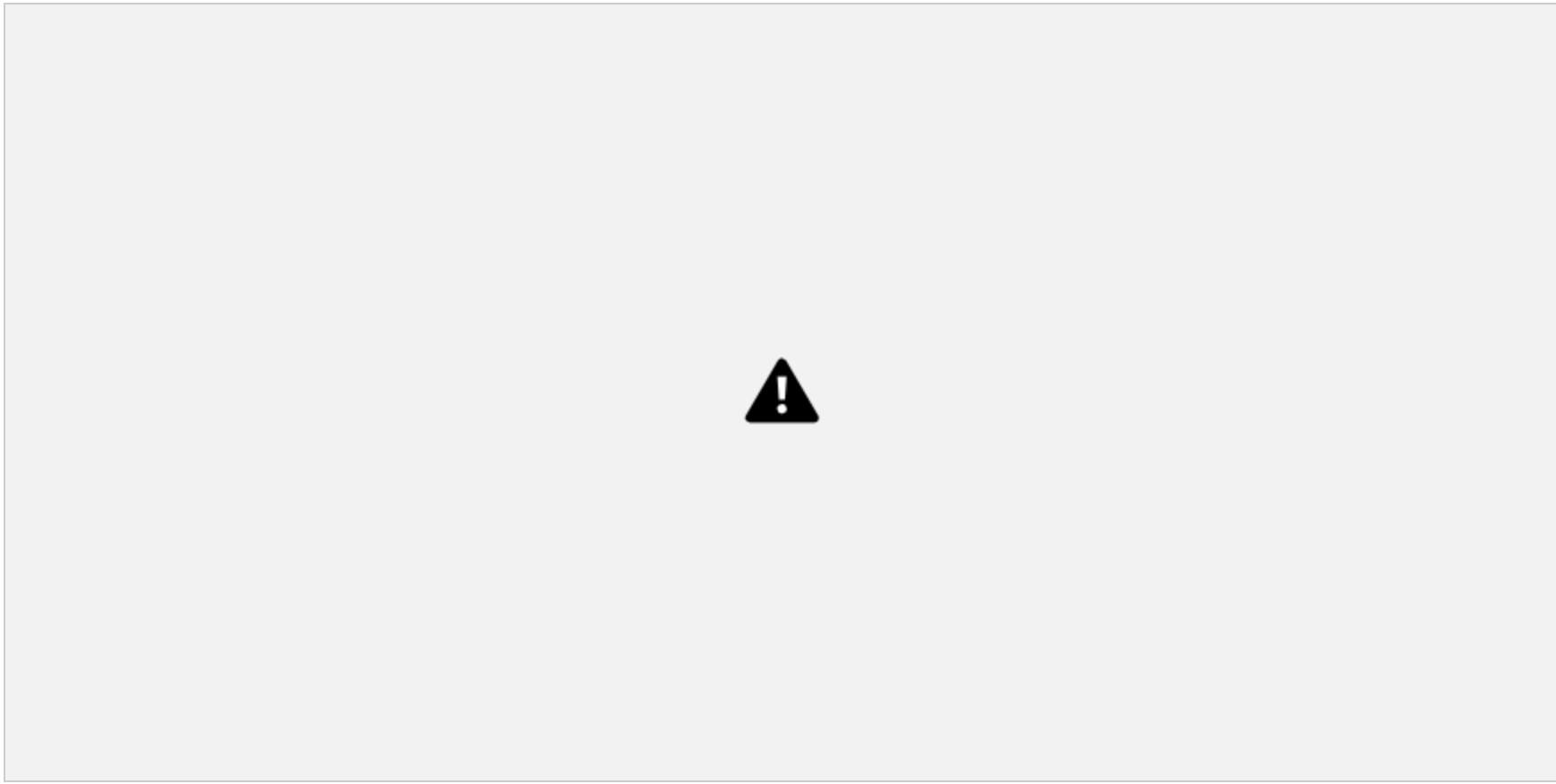
Higher job demand

"We defined exposure as job strain (high demands and low control) versus no strain (all other combinations) according to the job-strain model."

(Michael Ingre, *Doctoral thesis*, 2017)

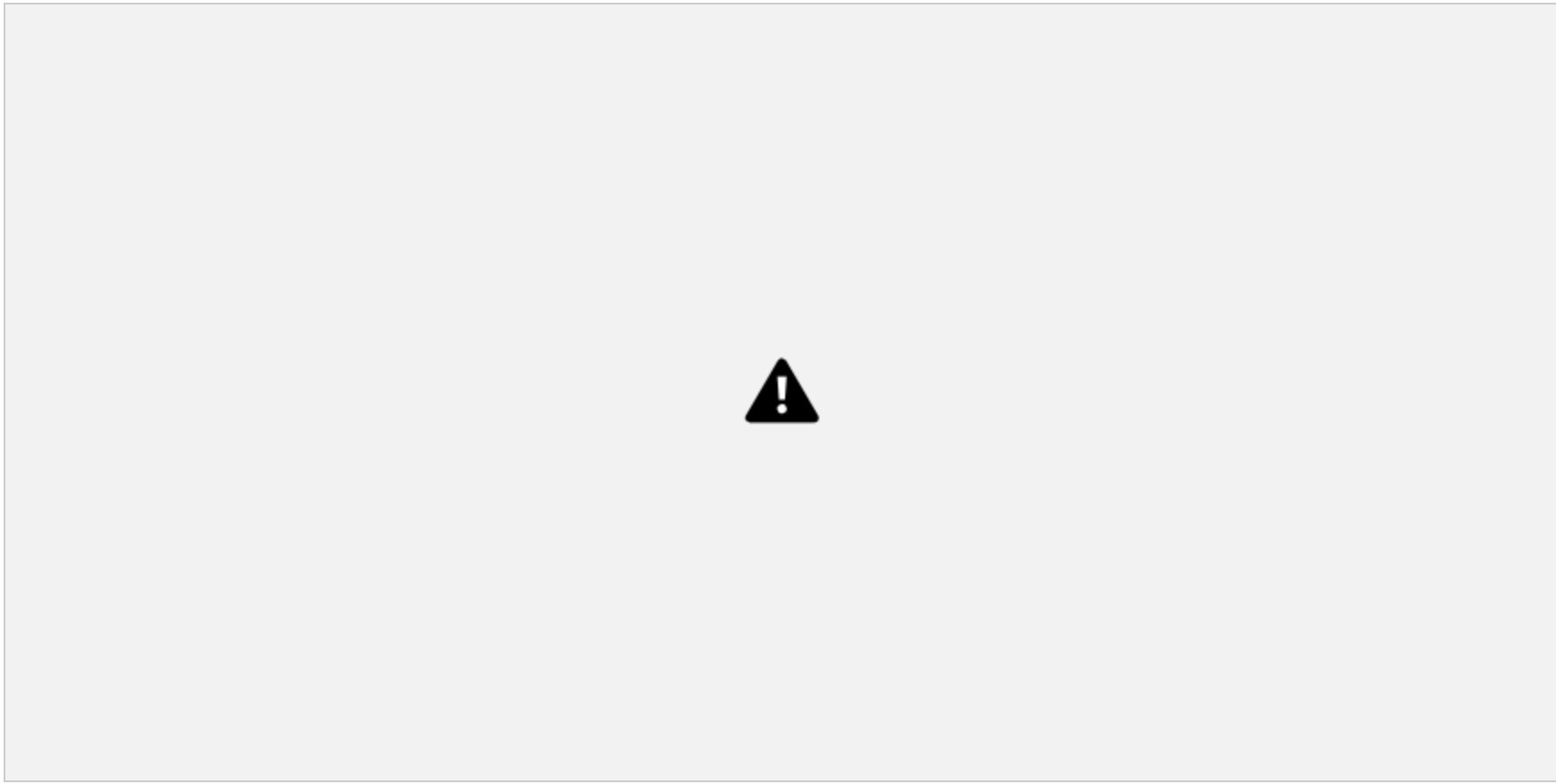
Let's consider two independent continuous random variables: A & B

The variables could represent Gin & Tonic..



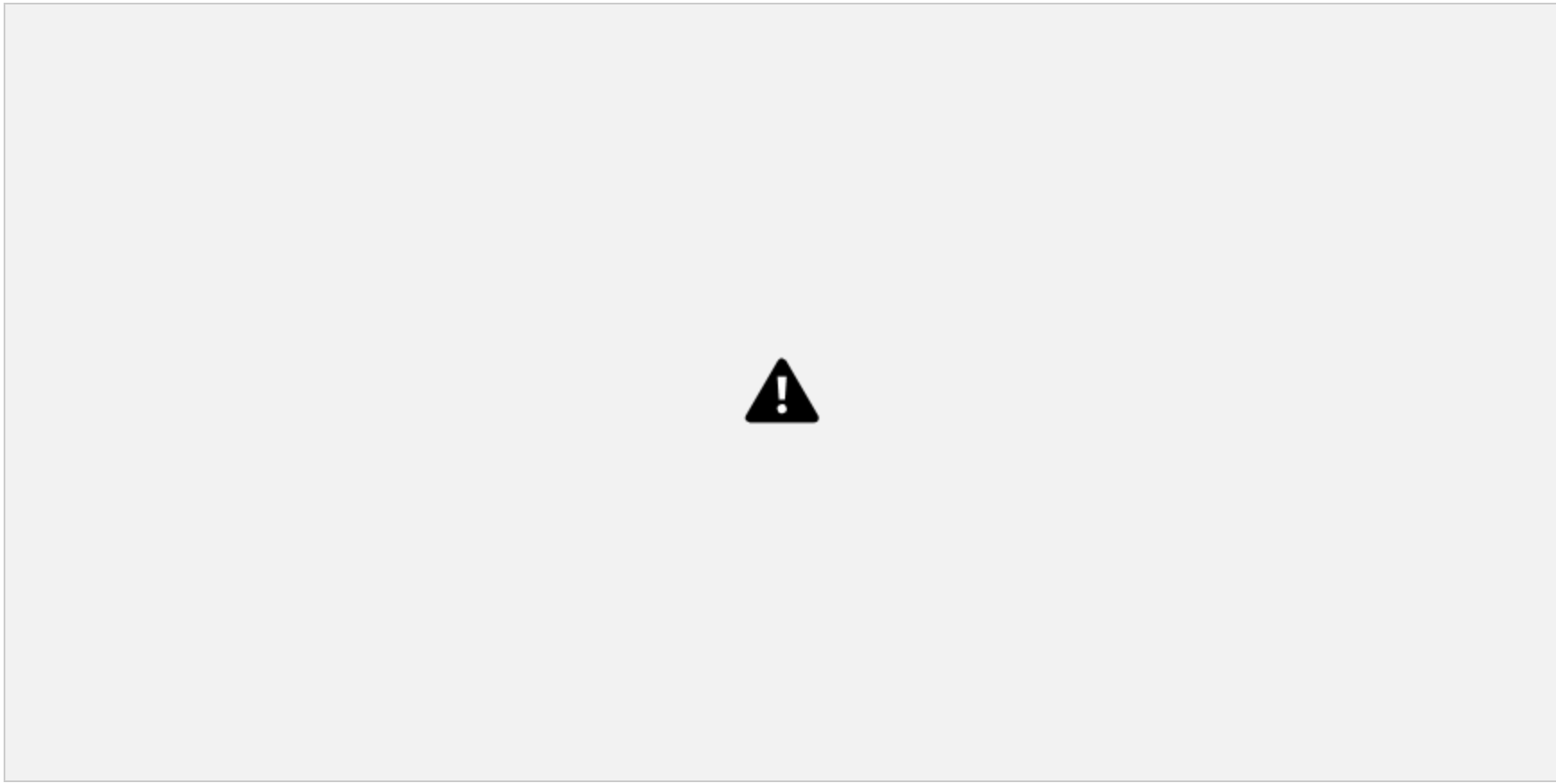
.. the two exposures in the job strain model..

Job control Job demand

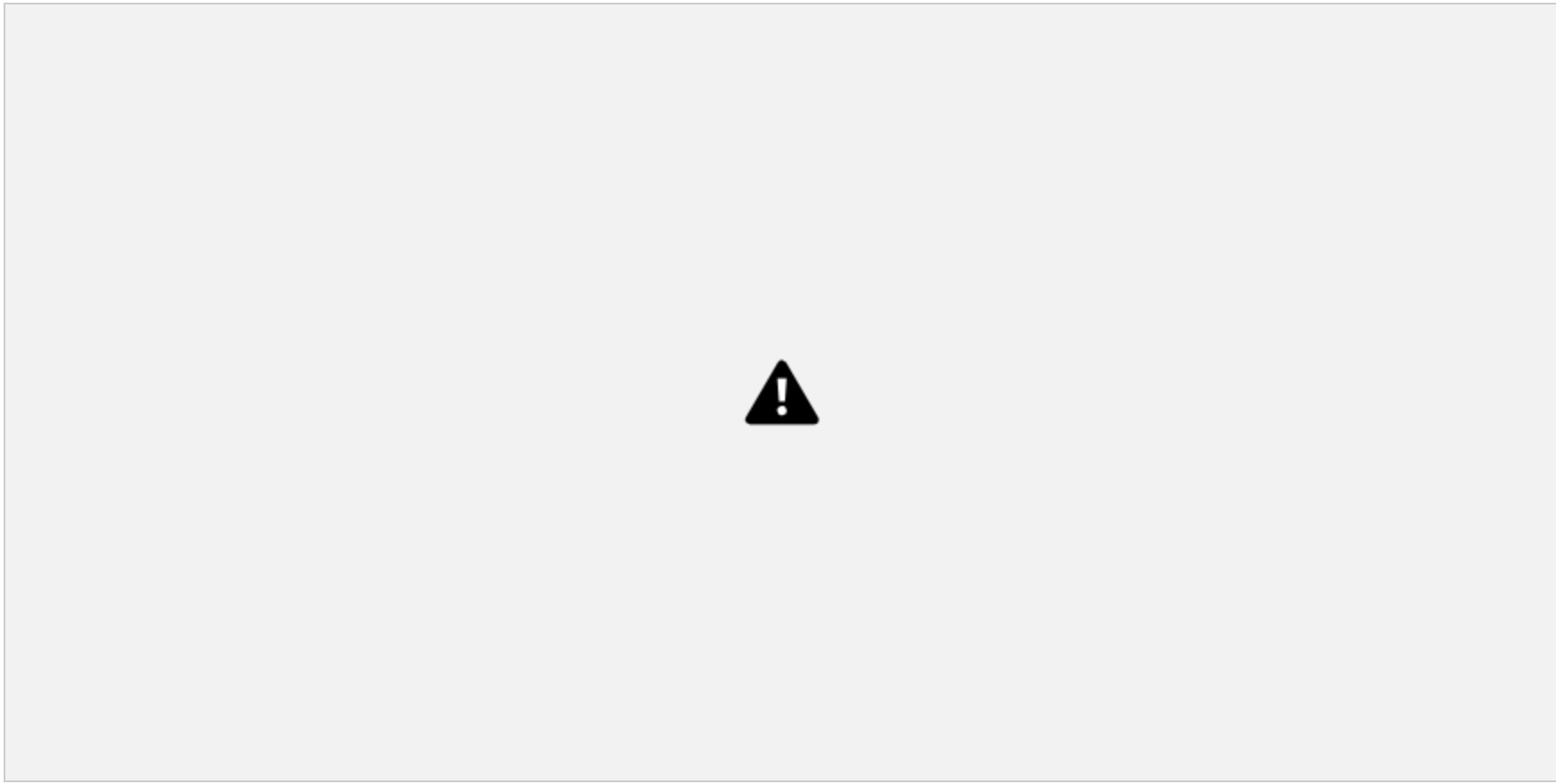


.. or the effort-reward imbalance model (ERI)

Perceived reward Perceived effort

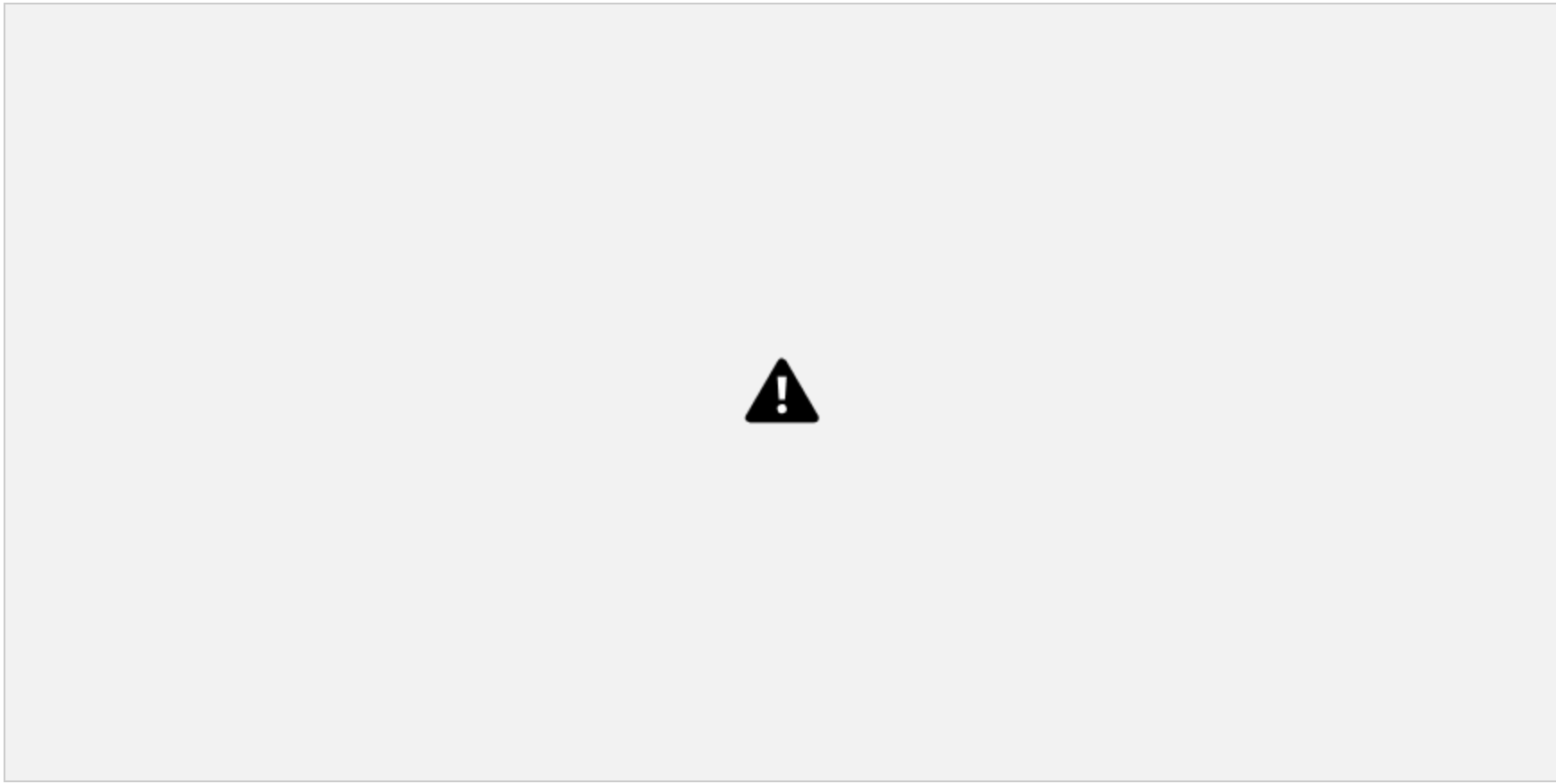


Composite variables by subtraction



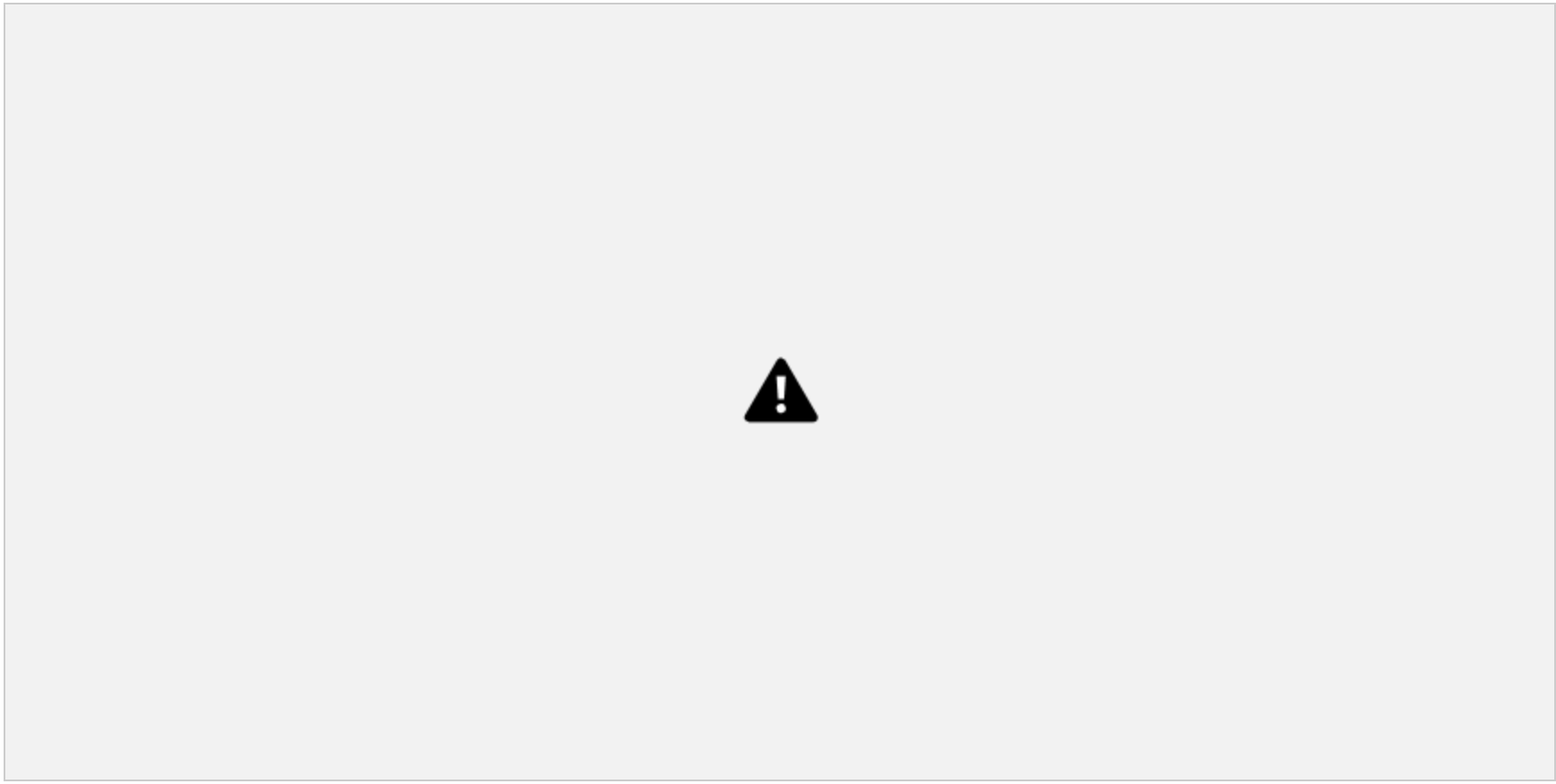
Composite variables by addition and multiplication

“Job strain” composite variable



Composite variables by division (i.e. ratio variables)

“ERI” composite variable



Binary and continuous “ERI” composite variable “ERI”

ERI<1 ERI>1

Binary and continuous “ERI” composite variable

An

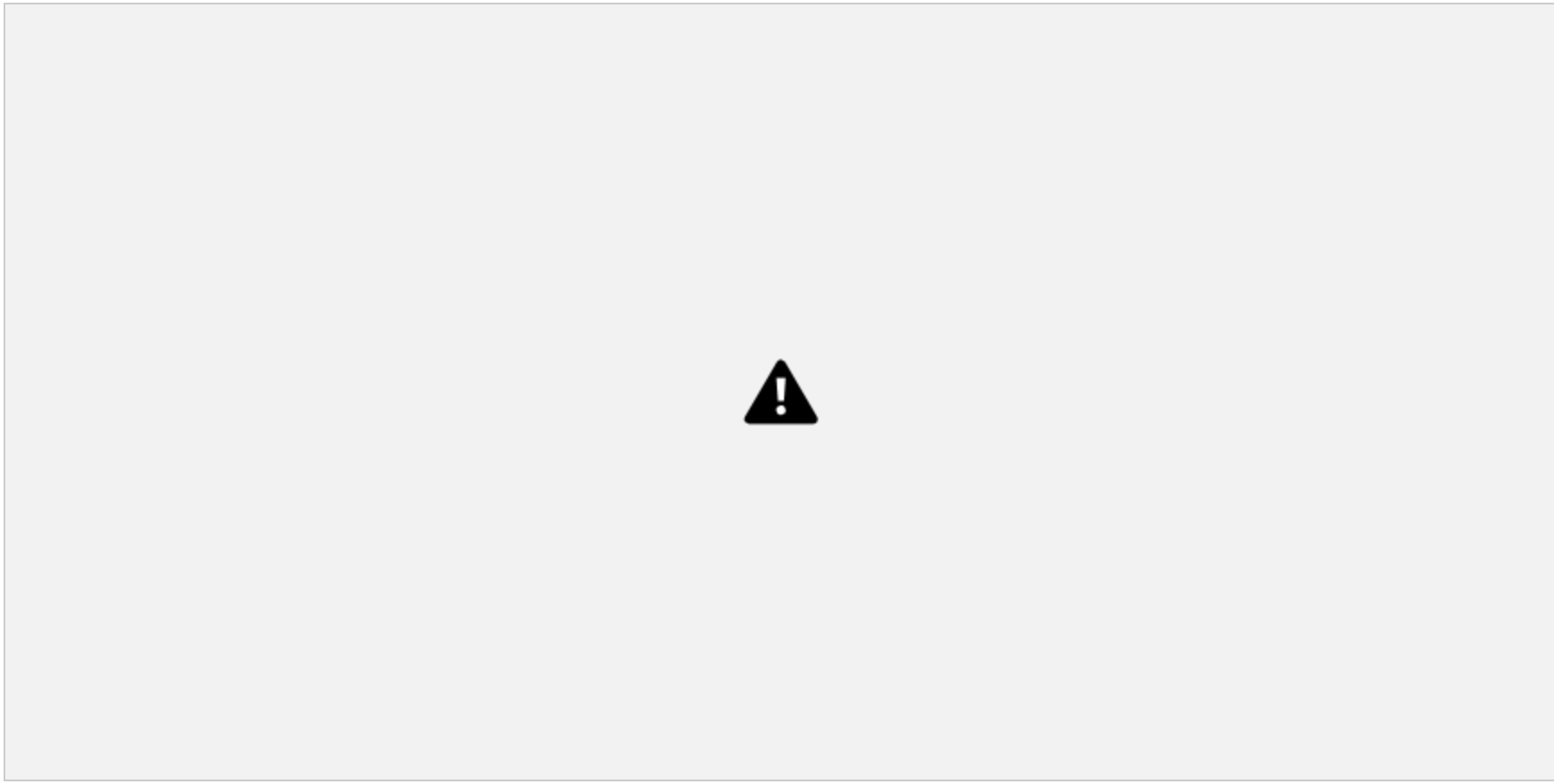
observed association can depend on a

"ERI"

single univariate association with only one of the constituent variables

ERI<1 ERI>1

Let's consider two independent continuous random variables: A & B



How to model the combined effect of two different exposures:

The full interaction model and the additive model

References:

Kronmal, R. A. (1993). Spurious Correlation and the Fallacy of the Ratio Standard Revisited. *Journal of the Royal Statistical Society. Series A,* , *156*(3), 379–392.

Brambor, T., Clark, W. R., & Golder, M. (2006). Understanding Interaction Models: Improving Empirical Analyses. *Political Analysis: An Annual Publication of the Methodology Section of the American Political Science Association*, *14*(1), 63–82.

https://en.wikipedia.org/wiki/Interaction_(statistics)

Modelling job strain and effort-reward imbalance

On median split data (four groups) there are exactly two different models to fit, that models the association of both exposures!

Study label	n	Events
Johnson1989	7219	
Alterman1994	1606	
Kivimäki2002	812	
Lee2002	35038	
Eaker2004	1328	
Eaker2004	1711	

407 CVDx----

283 CHDm-x---

73 CVDmx---

146 CHD--x--

31 CHD--x--

118 CHD--x--

Demiral2006 450 36 CHD-x--- Kuper2006 19565 89 IHD--x-- Kuper2006 15972 55 IHD--x-- Netterstrøm2006 659 47 IHD--xx- Tsutsumi2006 3178 35 CVDm--x-- André-Petersson2007 3063 114 MIx-x-- André-Petersson2007(4707 38 MIx-x-- Bonde2009 18258 101 IHD-x--- Netterstrøm2010 595 34 IHD--x-- Netterstrøm2010 551 70 IHD--x-- Kivimäki2012 197473 2358 CHD-xx-- Slopen2012 22086 170 MI--x-- Padyab2014 36668 454 CVDm---x- Padyab2014 38320 141 CVDm---x- Szerencsi2014 11489 309 CVDx---- Torén2014 6070 1052 CHD--x-- Schiöler2015 75236 1884 CHD--x--

“job strain” and CHD

OutcomeM$_J$M$_B$M$_Q$M$_A$M$_I$

Systematic review of

- The full interaction model is indicated to the right (M_I)
- Next is the additive model without interaction term (M_A)
- The rest are composite variable models:
  - The quadrant model (M_Q)
  - The binary model (M_B)
  - A “Johnson” type model (M_J)
- Studies already included in Kivimäki *et al.* (2012) were excluded from this analysis
- No clinical groups

(Michael Ingre, *Doctoral thesis*, 2017)

Published criticism of composite variable models in job strain/ERI

Kasl, S. V. (1996). The influence of the work environment on cardiovascular health: a historical, conceptual, and methodological perspective. Journal of Occupational Health Psychology, 1(1), 42–56.

Ingre, M. (2015). Excuse me, but did the IPD-work consortium just “falsify” the job-strain model? Scandinavian Journal of Work, Environment & Health.

Ingre, M. (2017). P-hacking in academic research: a critical review of the job strain model and of the association between night work and breast cancer in women. Department of Psychology, Stockholm University.

Mikkelsen, S., Andersen, J. H., Bonde, J. P., Hansen, Å. M., Kolstad, H., & Thomsen, J. F. (2017). Job strain and clinical depression. Psychological Medicine, 1–2.

Mikkelsen, S., Andersen, J. H., & Ingre, M. (2018). Re: Effort–Reward Imbalance at Work and Incident Coronary Heart Disease. Epidemiology.

Ingre, M., Andersen, J. H., & Mikkelsen, S. (2018). Re: Re: Effort-Reward Imbalance at Work and Incident Coronary Heart Disease. Epidemiology .

How are composite variable models defended in the literature?

- Reference to authority

  → *"This is not how Siegrist, the hypothesis generator, recommends the construct of effort–reward imbalance to be quantified."*

- Consistent with

  →"*First, we consider the effort–reward ratio, an investigator-based algorithm quantifying the mismatch between effort and reward at individual level, consistent with the effort–reward theory ..."* ▪

- Whataboutism

  → *"One well-known example from epidemiology is the body mass index, which combines height and weight into a sensitive indicator of cardio-metabolic risk"*

How are composite variable models defended in the literature?

- Reference to authority
  - → *"This is not how Siegrist, the hypothesis generator, recommends the construct of effort–reward imbalance to be quantified."*
- Consistent with
- Deflection
  - →"*First, we consider the effort–reward ratio, an investigator-based*
- An attempt to end the discussion, right there *algorithm quantifying the mismatch between effort and reward at*
- Makes it personal
  - *individual level, consistent with the effort–reward theory ..."*
- The authority may be wrong!
  - Whataboutism
    - → *"One well-known example from epidemiology is the body mass index, which combines height and weight into a sensitive indicator*

of cardio-metabolic risk"

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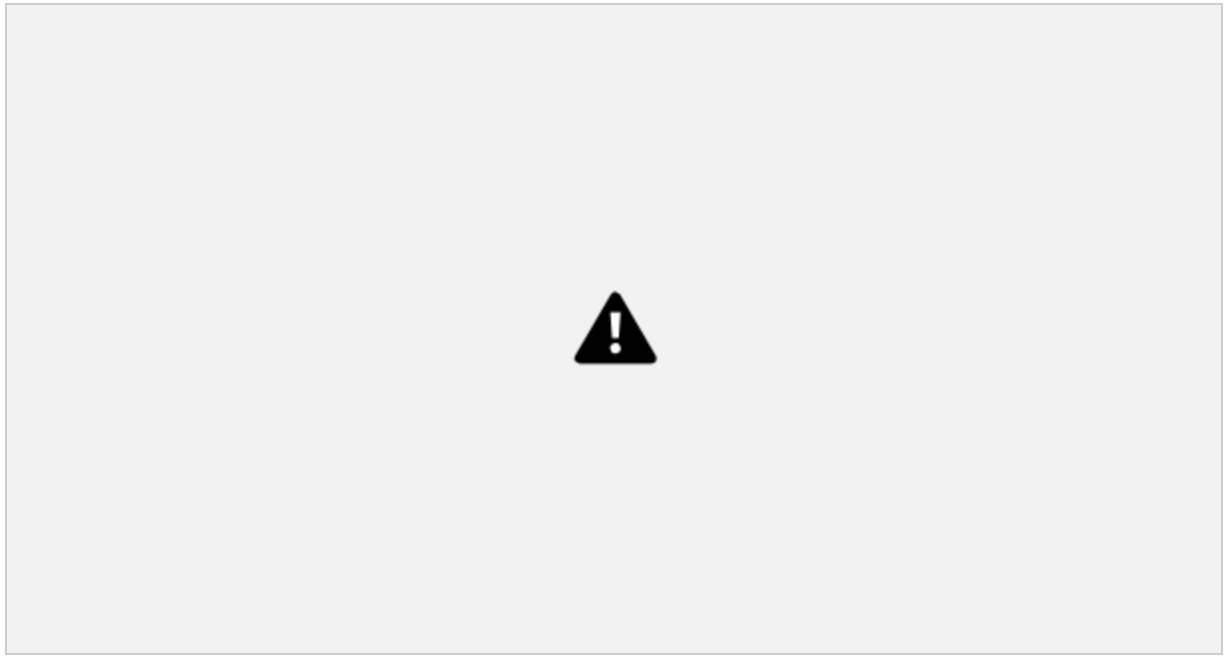
  → *"One well-known example from epidemiology is the body mass index, which combines height and weight into a sensitive indicator of cardio-metabolic risk"*

How are composite variable models

defended in the literature?

- Observing an association on a composite variable is indeed *consistent with* the hypothesis of an interaction
  - Reference to authority
- But it is also *consistent with* the hypothesis of a univariate association

  → *"This is not how Siegrist, the hypothesis generator, recommends* with only one of the two constituent variables



the construct of effort–reward imbalance to be quantified."

- Consistent with

→"*First, we consider the effort–reward ratio, an investigator-based algorithm quantifying the mismatch between effort and reward at individual level, consistent with the effort–reward theory*

...” ▪ Whataboutism

→ *“One well-known example from epidemiology is the body mass index, which combines height and weight into a sensitive indicator of cardio-metabolic risk”*

● Occam’s Razor suggest that we should accept the simplest explanation

How are composite variable models defended in the literature?

▪ Reference to authority

→ *“This is not how Siegrist, the hypothesis generator, recommends the construct of effort–reward imbalance to be quantified.”*

▪ Consistent with

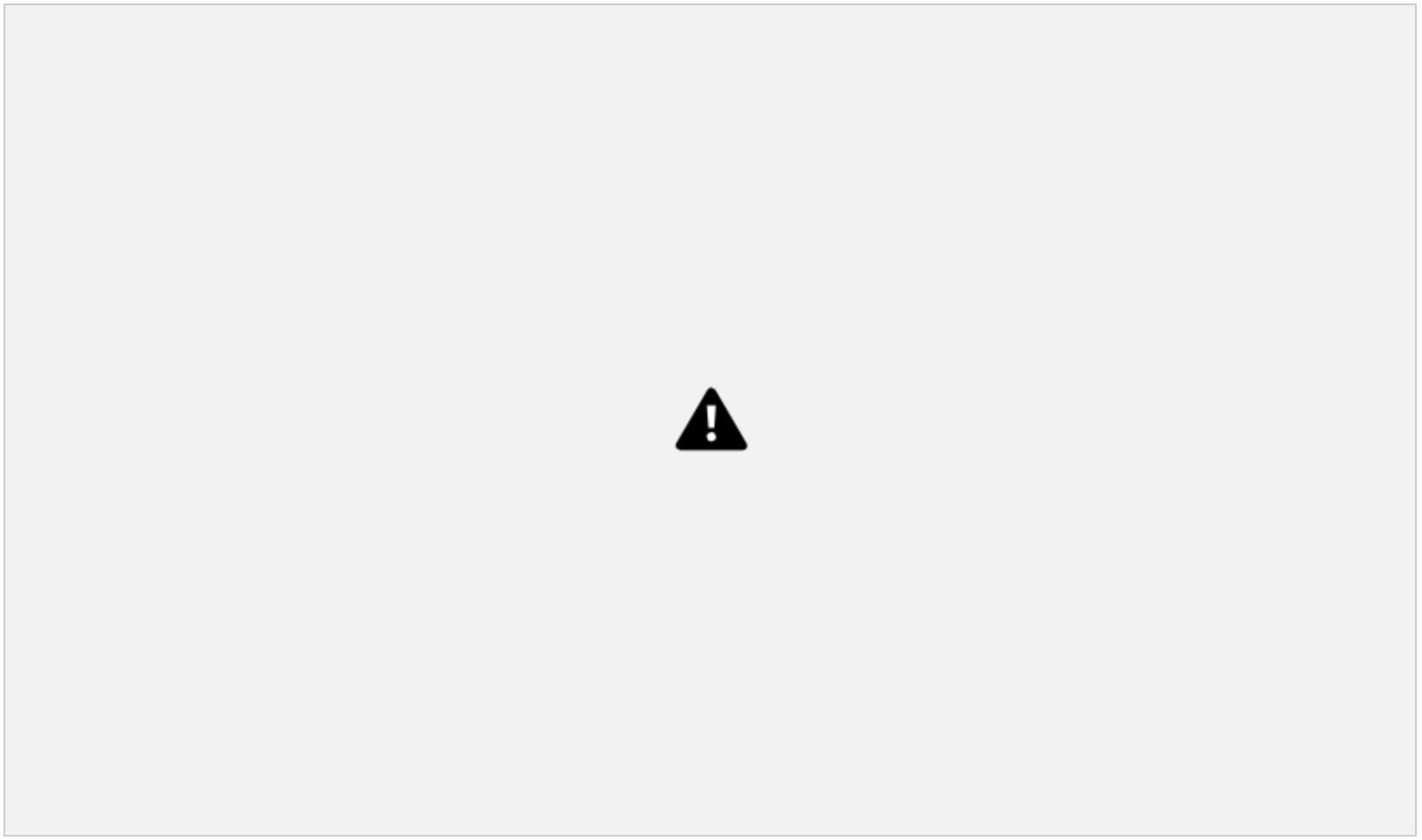
→“*First, we consider the effort–reward ratio, an investigator-based algorithm quantifying the mismatch between effort and reward at individual level, consistent with the effort–reward theory ...”* ▪ Whataboutism

→ *“One well-known example from epidemiology is the body mass index, which combines height and weight into a sensitive indicator of cardio-metabolic risk”*

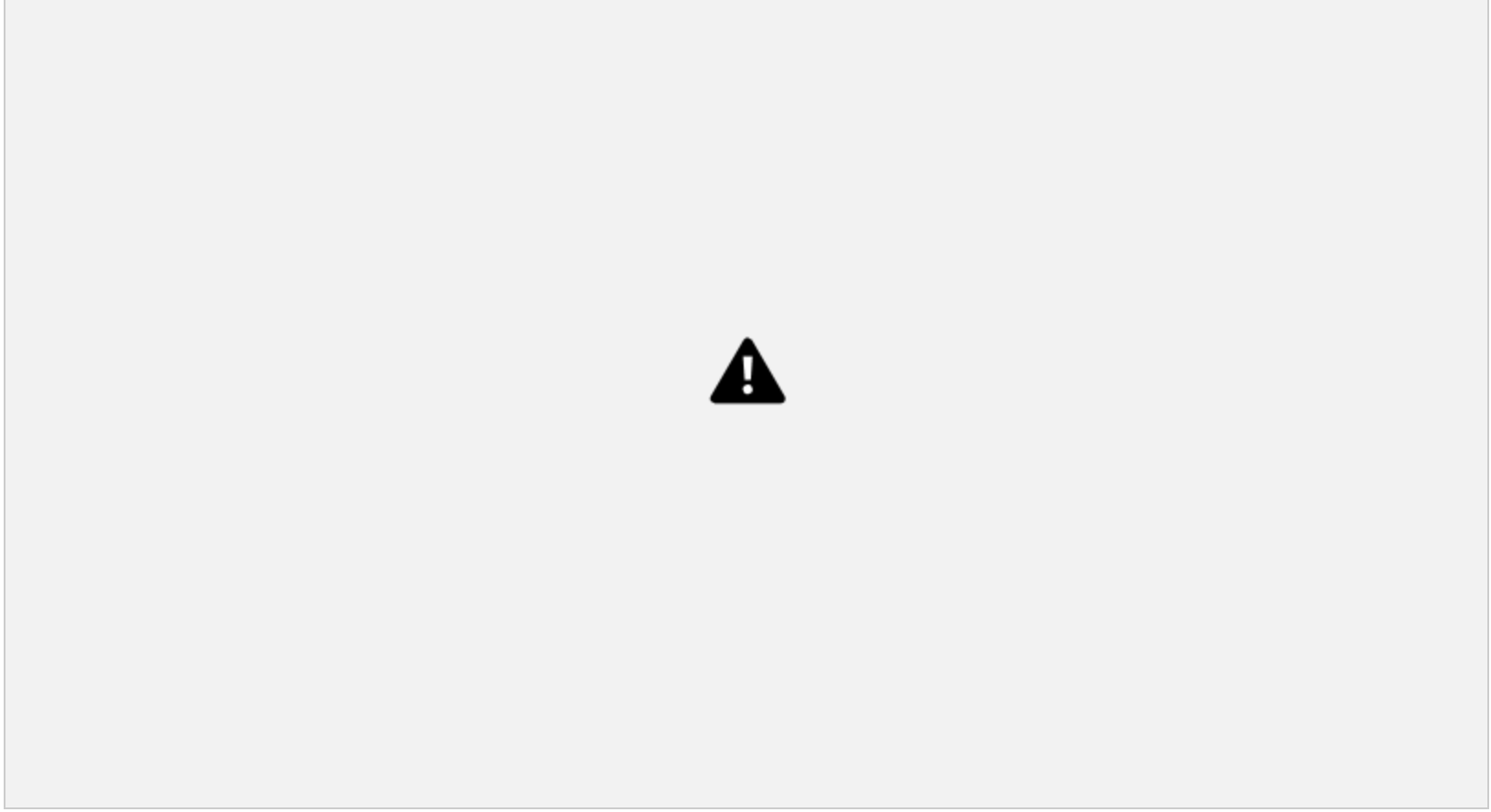
Weight and height in the adult population of: National Health and Nutrition Examination Survey (NHANES)

Body Mass Index and height in the NHANES

Body Mass Index and weight in the NHANES



Body Mass Index and weight in the NHANES



Whatabout BMI? is not a good argument for the validity of composite variable models!

Modelling the specific form of the interaction described by BMI:

Kronmal, R. A. (1993). Spurious Correlation and the Fallacy of the Ratio Standard Revisited. *Journal of the Royal Statistical Society. Series A,* , *156*(3), 379–392.

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Whataboutism

→ *"One well-known example from epidemiology is the body mass index, which combines height and weight into a sensitive indicator of cardio-metabolic risk"*

How are composite variable models defended in the literature?

- Reference to authority

  → *"This is not how Siegrist, the hypothesis generator, recommends the construct of effort–reward imbalance to be quantified."*

  Be critical when rhetorics, rather than logic

- Consistent with

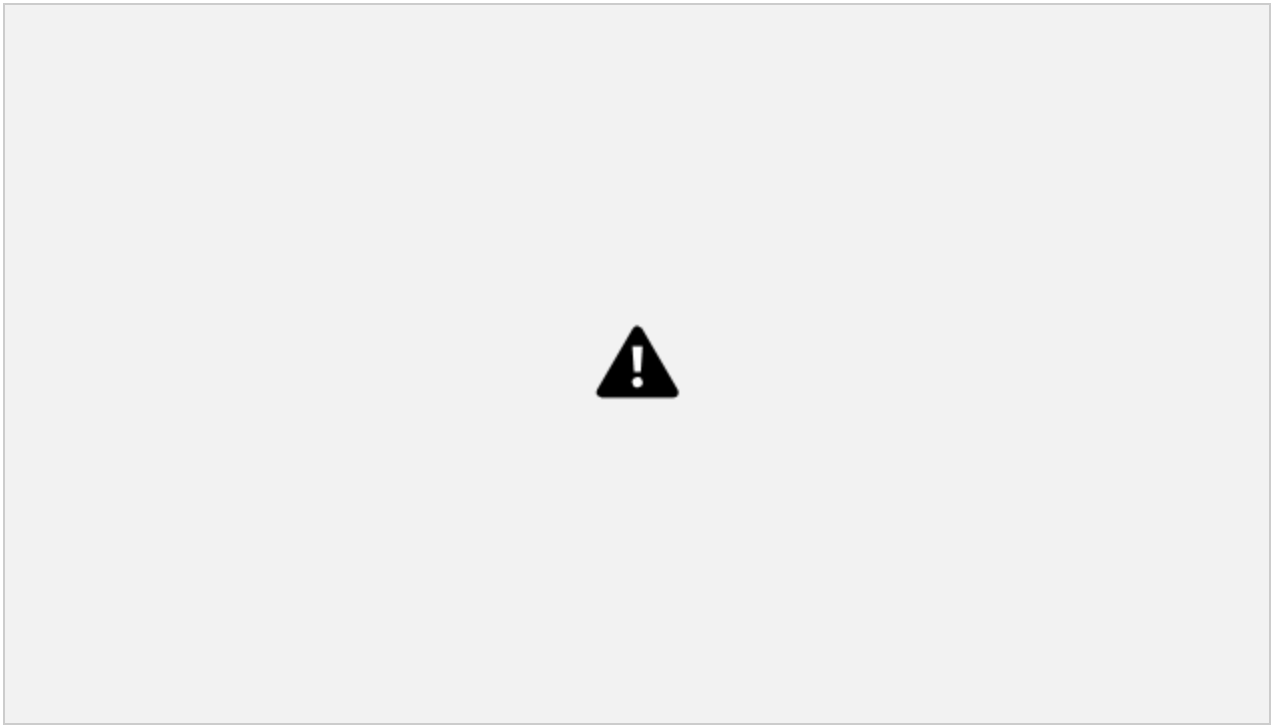
and reason, is used to motivate research

→"*First, we consider the effort–reward ratio, an investigator-based algorithm quantifying the mismatch between effort and reward at individual level, consistent with the effort–reward theory ...*"

- Whataboutism

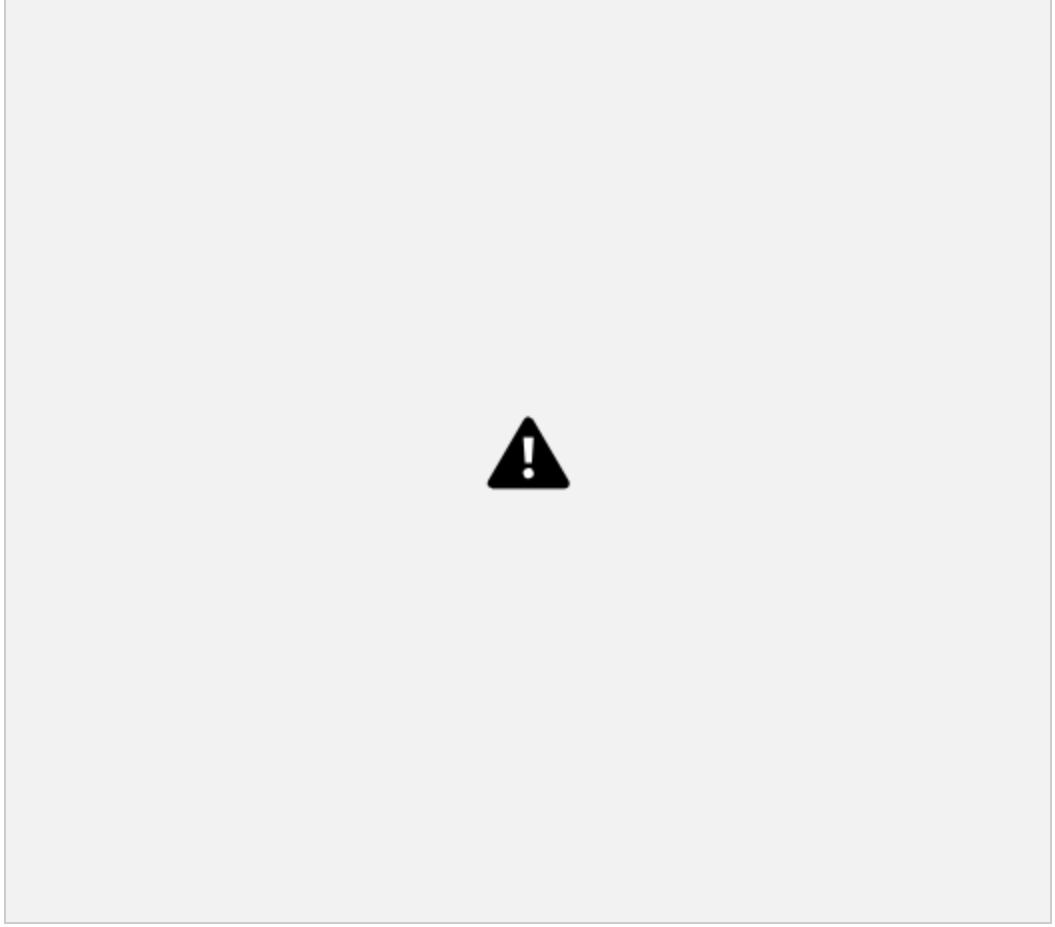
→ *"One well-known example from epidemiology is the body mass index, which combines height and weight into a sensitive indicator of cardio-metabolic risk"*

Transforming estimates from the quadrant model to the full interaction model



(Michael Ingre, *Doctoral thesis*, 2017)

Job strain and coronary heart disease: A bias adjusted meta analysis



- 27 cohorts,
- 387k subjects
- 6241 CHD cases

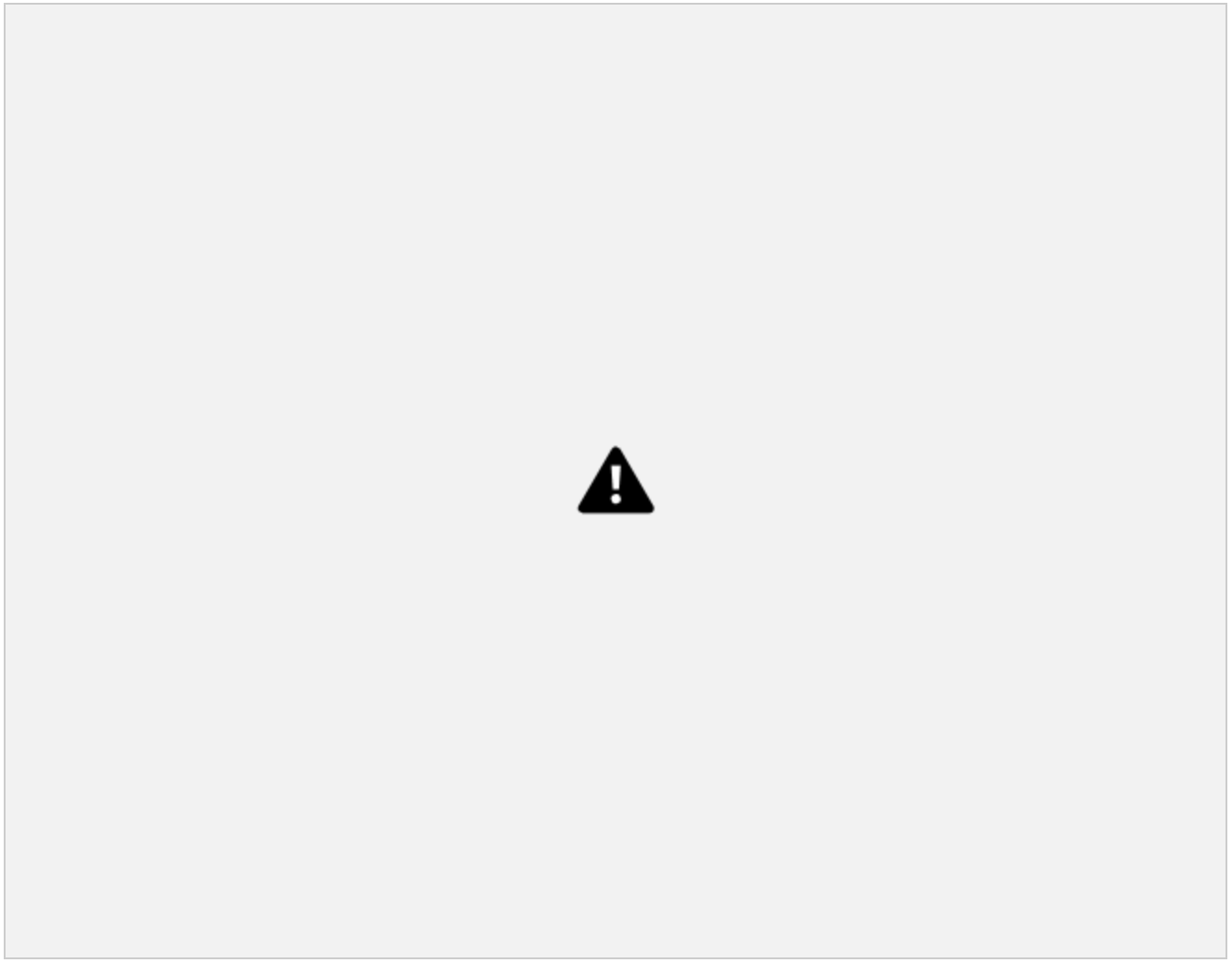
- Because no studies reported the proper interaction model, only transformed estimates from studies reporting the *quadrant* model were included

- Studies already included in Kivimäki *et al.* (2012) were excluded from the analysis, to not be counted twice

(Michael Ingre, *Doctoral thesis,* 2017)

Job demand and job control

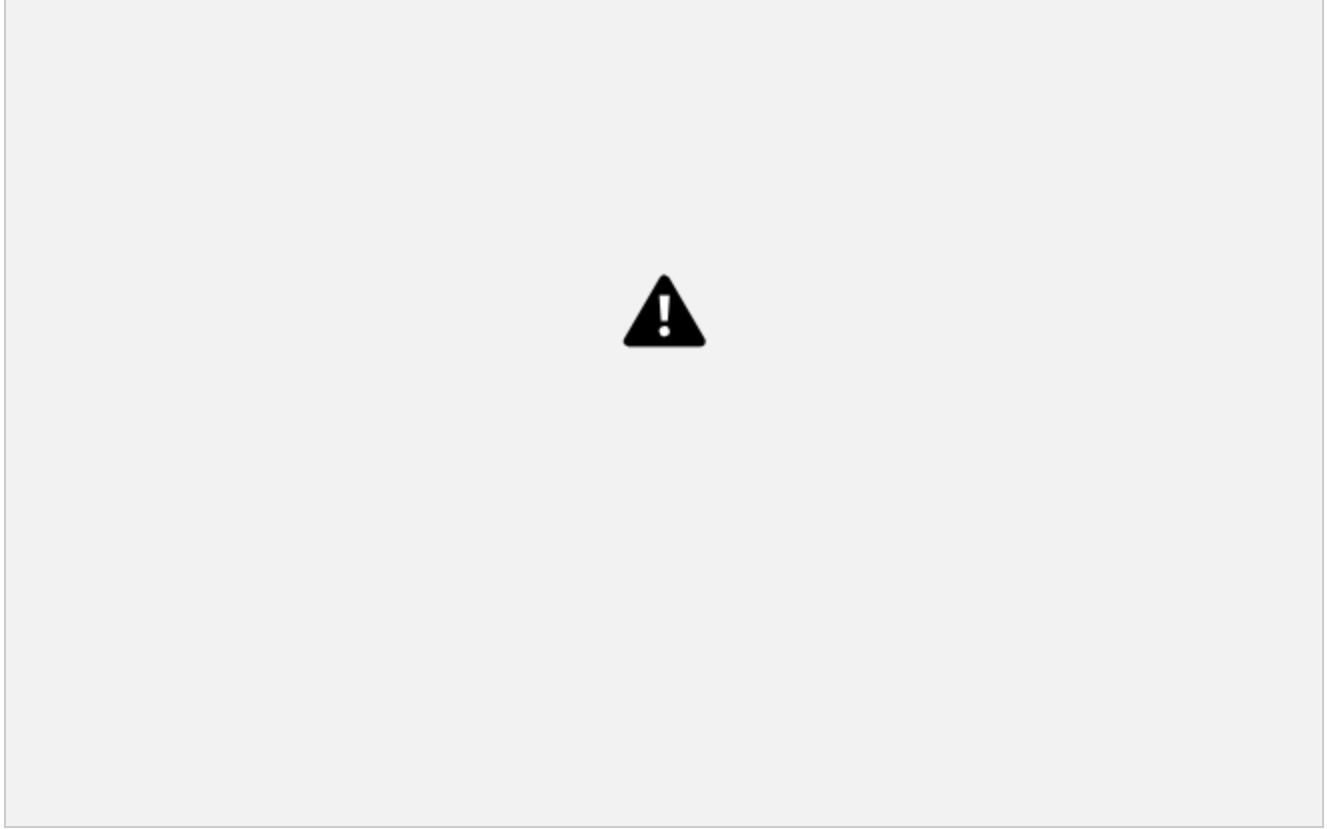
29 cohorts, 466k subjects and 6836 CHD cases



(Michael Ingre, *Doctoral thesis*, 2017)

Job demand and job control 29

cohorts, 466k subjects and 6836 CHD cases



It appears that the job strain theory is not supported by data

(Michael Ingre, *Doctoral thesis*, 2017)

Summary: composite variable models in occupational stress research

- Almost forty years of research
- Hundreds of researchers
- Thousands of publications
- Millions in spent research funding

- Researchers are still arguing along the lines of:

  → Observing people getting drunk on Gin Tonics, is evidence of an interaction between Gin and Tonic*

- How did we get to this point?