Measurement error in nutritional epidemiology:

Challenges, current practice, and the scope for improvement

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Topic Group 4: Measurement error

- Laurence Freedman, Gertner/IMS , Co-Chair
- Victor Kipnis, NCI, Co-Chair
- Raymond Carroll, Texas A&M
- Veronika Deffner, Munich, LMU
- Kevin Dodd, NCI
- Paul Gustafson, U. British Columbia
- Ruth Keogh, LSHTM
- Helmut Kuechenhoff, Munich, LMU
- Pamela Shaw, U. Pennsylvania
- Janet Tooze, Wake Forest School of Medicine

Outline

1. Aims of this topic group
2. Results from a literature review
3. Overview of a guidance paper for nutritional epidemiology
4. Further challenges in this area

Aims of Topic Group 4: Measurement error

Aims

1. Increase the awareness of the implications of measurement error and misclassification for our investigations among biostatisticians and epidemiologists
2. Point to methods to address problems arising from measurement error.

Current projects

1. Literature surveys of use of methods to deal with measurement error
2. Guidance paper for nutritional epidemiologists
3. Guidance paper for biostatisticians

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Literature survey

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Aims

1. To assess the current practice for acknowledging and addressing measurement error in epidemiologic/observational studies
2. To identify knowledge gaps and opportunities for improvement

4 survey areas

1. Nutritional intake cohort studies (Pamela Shaw/Ruth Keogh)
2. Dietary intake population surveys (Kevin Dodd)
3. Physical activity cohort studies (Janet Tooze)
4. Air pollution cohort studies (Veronika Deffner/Helmut Kuechenhoff)

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Literature survey: “Search A” (51 papers)

Survey of recent articles to assess how often articles acknowledged and/or addressed measurement error

	N	%
Mentioned measurement error as a potential problem	48	94%
Used a method to adjust for measurement error	5	10%
Categorization of exposure	50	98%

- Most people who mentioned error as a problem made an incomplete/incorrect claim
- Common belief: categorization will lower impact of measurement error in the analysis
- Common in the cohort studies to have multiple covariates with error: e.g. diet, physical activity, smoking, alcohol intake
- Lack of awareness of the impacts of measurement error

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Literature survey: “Search B” (27 papers)

Survey of recent articles that adjusted for measurement error to describe methods in current practice

Method used	N	%
Regression calibration	26	96%
Simulation extrapolation (SIMEX)	1	4%
Other	1	4%

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A guidance paper for nutritional epidemiologists

Aims of the paper

- Outline sources of error in measures of dietary intake and how error can be modelled
- Illustrate the impact of different types of measurement error
- Summarise methods for correction of measurement error
  - Focus on Regression calibration
- Make recommendations for the handling and reporting of measurement error

Different types of measurement error

Notation

X: True exposure

X^*: Measured exposure, which is subject to error

Classical error

$$X_i^* = X_i + U_i$$

Systematic error

$$X_i^* = \alpha_0 + \alpha_X X_i + U_i$$

Person-specific error

$$X_i^* = \alpha_0 + \alpha_X X_i + s_i + U_i$$

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What are we trying to measure?

Definition: 'usual' intake

Average daily intake over a particular time frame relevant to the hypothesized association between the dietary exposure and the outcome of interest

How do we measure it?

- Biomarkers
  - Gold standard, but expensive and only exist for a few nutrients
- Food frequency questionnaires
  - Structured questionnaire, with recall of diet over a given period
  - main instrument in prospective cohort studies
- 24-hour recalls and short term food diaries
  - More detailed and do not require long term recall
  - Expensive: used in calibration sub-studies

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Effects of measurement error

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Y: outcome of interest

Z: perfectly measured covariates

Outcome model using true exposure

$$\text{logit Pr}(Y = 1|X, Z) = \beta_0 + \beta_X X + \beta_Z Z$$

Outcome model using error-prone exposure (the 'naive' model)

$$\text{logit Pr}(Y = 1|X^*, Z) = \beta_0^* + \beta_X^* X^* + \beta_Z^* Z$$

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Type of measurement error	Direction of bias
Classical	β_X^*: Towards the null
	β_Z^*: Either direction
Systematic	β_X^*: Either direction
	β_Z^*: Either direction

Methods for measurement error correction

What do we need?

- Information on the form of the error
- Ideally we would observe X in a subset of individuals
- The next best thing: estimate the form of error by using...
  - A sub-study in which an unbiased measure is available: biomarker, 24HR, food record
  - Repeated measures in a sub-study: if error assumed classical

Typical scenario in a prospective cohort

- FFQ observed for everybody
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Regression calibration

- Replace X by $E(X|X^*, Z)$
- Fix up the standard errors

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$$R_i = X_i + U_i \text{ [This may be unreasonable but let's go ahead]}$$

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- Use $E(X|Q,Z) = E(R|Q,Z)$ in place of X
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What can we reasonably expect from investigators?

- Acknowledgement of measurement error and discussion of what its effects could be
- If it is possible with the data available: make corrections for error, e.g. using regression calibration
- Discuss the assumptions made in the error correction
- If corrections are not possible, conduct sensitivity analyses

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Challenges and scope for further developments

- We lack biomarkers
- People like to categorise things but correction methods don't easily accommodate this
- How can we accommodate ...
  - dietary intake changing over time?
  - latency of the association between dietary intake and the outcome?
- Correction methods do not easily accommodate flexible modeling of exposure-outcome associations
- How do we handle both missing data AND measurement error?
- Study design: letting people know what they need to include to perform corrections for measurement error

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