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Contribution of Chronic Conditions to the Disability Burden Using a Multinomial Outcome: Results for the Older Population in Belgium and Brazil, 2013

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Introduction

Disability

- Reality in developed and developing countries
- Population ageing
- Burden of chronic diseases: main causes of disability

Social burden: ↓ quality of life and ↑ health care use

Mortality

- No longer sufficient to measure population health

Morbidity

- Important measure of population health
- Lack of standard assessment method

Introduction

Methods to assess disability by cause

Longitudinal studies

- "Gold standard"
- Expensive and limited sample size

Cross-sectional studies

1. Cause-elimination methods
2. Population attributable fraction (PAF)
3. Average attribution method
4. Global Burden of Diseases (years lived with disability)
5. **Attribution method**

Introduction

Attribution method

- Nusselder and Looman, 2004[1]
- Binomial additive hazards model
- Partition of disability into additive contributions of causes
- Takes into account
  - Multimorbidity
  - Disability is present in individuals without chronic conditions
- Widely used: The Netherlands, Belgium, Germany, China, and Brazil

[1] Nusselder, W.J., Looman, C.W. (2004). Decomposition of differences in health expectancy by cause. Demography, 41(2): 315-334.

Introduction

Extension of the attribution method to multinomial responses[1]

- Disability: often measured as a multi-category variable in surveys
- Different severity levels
  - No disability
  - Mild disability
  - Severe disability
- First application of the method

[1] Yokota, R.T.C., Van Oyen, H., Molenberghs, G. (2015). Use of a multinomial additive hazards model to assess the disability burden using cross-sectional data. Master Thesis, UHasselt, Belgium.

Objective

To investigate the contribution of chronic conditions to the disability burden in the older population in Brazil and Belgium using the extended attribution method.

Methods

Health Interview Surveys, 2013

- Independent household surveys
- Individuals aged 65 years or older

	BRAZIL	BELGIUM
Sample size	N = 60,202	N = 10,829
Response rate	77%	57%
Individuals ≥ 65 years	N = 7,123	N = 1,857

- Chronic conditions and disability: common in the 2 surveys

Methods

Chronic conditions

- **Brazil:** *Has a doctor ever given you the diagnosis of...?*
- **Belgium:** *During the past 12 months, have you had...?*

1. Hypertension
2. Diabetes
3. Heart diseases
4. Stroke
5. Asthma
6. Arthritis
7. Back pain
8. Depression
9. Chronic respiratory diseases
10. Cancer
11. Chronic kidney diseases

Methods

Disability

- **Activities of daily living (ADL):** eating, showering, using the toilet, dressing/undressing, transferring from bed, transferring from chair

Country	Question	Possible answers
Brazil	*Which degree of difficulty do you have to...?*	1. No difficulty 2. Some difficulty 3. A lot of difficulty 4. Unable
Belgium	*Do you usually have difficulty in doing... by yourself?*	1. No difficulty 2. Some difficulty 3. A lot of difficulty 4. Cannot achieve by myself

Multinomial outcome:

- No disability (reference)= 1
- Mild disability = 2
- Severe disability = 3 or 4

Methods

Multinomial additive hazards model

$$Y_{ij} \sim Multinomial(n_i, \pi_{ij})$$

$$\pi_{ij} = \left[1 - \exp(-\sum_{j=1}^{c} \eta_{ij})\right] \left(\frac{\eta_{ij}}{\sum_{j=1}^{c} \eta_{ij}}\right)$$

$$\eta_{ij} = \alpha_{aj} + \sum_{d=1}^{m} \beta_{adj}(X_{di} X_{ai})$$

- Y_{ij}: multinomial response variable (disability) for each individual i
- π_{ij}: probability that individual i is disabled for each j category of the outcome
- η_{ij}: total disability rate for each individual i for each j category of the outcome
- α_{aj}: background disability rate for each age group a (65-74 years; 75+ years) for each j category of the outcome
- β_{adj}: disability rate (disabling impact) for each age group a, condition d, and j category of the outcome
- X_{di}: indicator variable for each condition d and each individual i
- X_{ai}: indicator variable for each age group a and individual i

Methods

Statistical Analysis

- Convergence problems in standard glm software: non-canonical link function
- Constrained optimization: linear inequality constraint

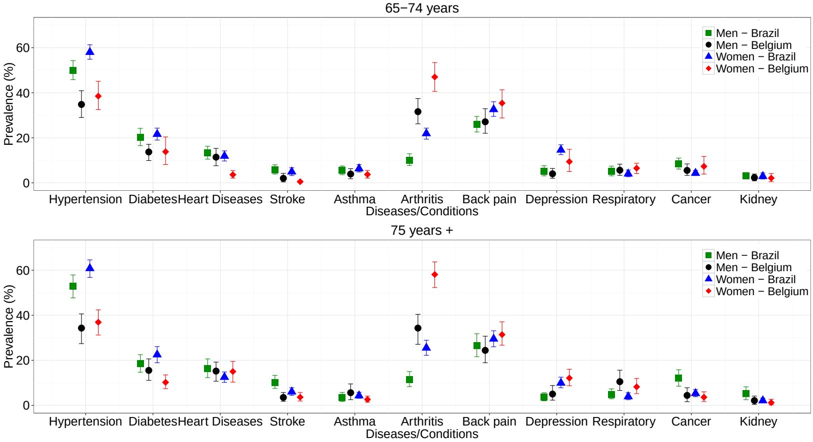
$$\boldsymbol{\eta_{ij} \geq 0}$$

$$\pi_{ij} = \left[1 - \exp(-\sum_{j=1}^{c} \eta_{ij})\right] \left(\frac{\eta_{ij}}{\sum_{j=1}^{c} \eta_{ij}}\right)$$

- R package: `addhaz`
- Separate models for Brazil and Belgium

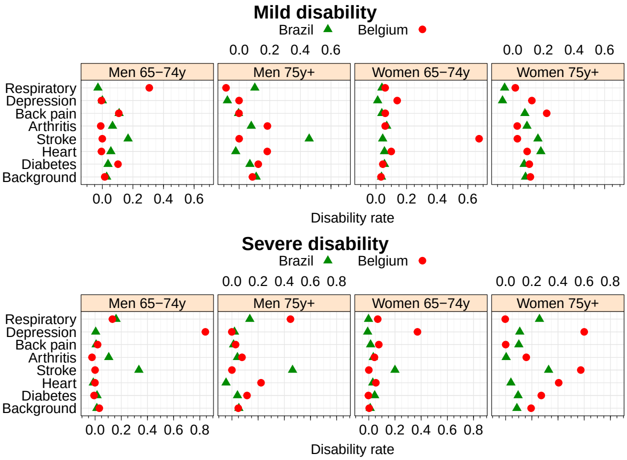
Results

Disease Prevalence



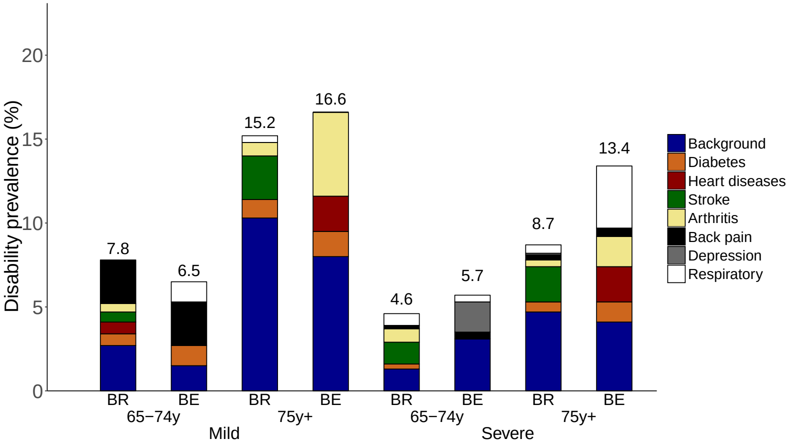
Results

Disability rates (disabling impacts)



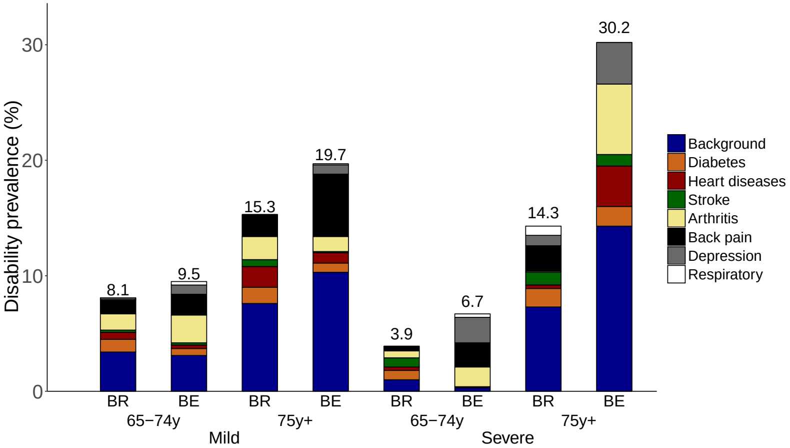
Results

Contribution to the disability prevalence - Men



Results

Contribution to the disability prevalence - Women



Limitations

- Causality assumption
  - Plausible: disease $\rightarrow$ disability
  - Cross-sectional data: disability incorrectly attributed to disease (disability $\rightarrow$ disease)
- Overestimation of background contribution
  - Under-reported and under-diagnosed diseases
  - Lack of information about dementia
- Differences in the disability and disease questions in the surveys
- Limited sample size
  - No adjustment for education level
  - Disease interaction

Conclusions

Mild disability prevalence

- Belgium > Brazil
- Exception: men aged 65-74 years
- Main contributors: musculoskeletal disorders

Severe disability prevalence

- Belgium > Brazil
- Substantial differences in the main contributors

Subgroup	Brazil	Belgium
Men		
65-74 years	Stroke	Depression
$\geq$75 years	Stroke	Respiratory
Women		
65-74 years	Diabetes	Depression
$\geq$75 years	Back pain	Arthritis

Thank you!

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Extra slides

Extra #1

Sample selection

Brazil

1. **Stratification:** state, municipality, urban/rural (census tracts)
2. **Clustering:** household, individual

Belgium

1. **Stratification:** region, province
2. **Clustering:** municipality, household, individual

Extra #2

Attribution method - rationale

- **Mortality**: one disease is assigned as underlying cause of death by the physician who fills in the death certificate
- **Disability (attribution method)**: to attribute each **disability** case reported in a survey to one single cause

Background

- Even if a person has only one disease: not necessarily the cause of the disability
- Disability can occur without any disease: physiological changes due to ageing
- Under-reporting and under-diagnosed diseases in the survey
- Diseases that cause disability not included in the survey

Extra #3

Assumptions

- Distribution of disability by cause at the time of the survey: diseases that are still present + background
- Disease hazards proportionally equal during the period preceding the survey
- Individuals from the same age group are exposed to the same background rate
- Causes of disability (diseases and background) act as independent competing causes
- The start of the time at risk for disability is similar for all causes

Extra #4

Definition of the multinomial response for disability

- $y_i = 0, 1, 2$
- Mutually exclusive response categories
- Constraint: $\sum_{j=0}^{c} Y_{ij} = 1$
- Re-writing the response as a multinomial response:

$$Y_{ij} = \begin{cases} 1, & \text{if } y_i = j \\ 0, & \text{otherwise} \end{cases}$$

$$\begin{array}{c} \\ i=1 \\ i=2 \\ \vdots \\ i=n \end{array} \begin{array}{c} \begin{array}{ccc} Y_1 & Y_2 & Y_3 \end{array} \\ \begin{pmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ \vdots & \vdots & \vdots \\ 1 & 0 & 0 \end{pmatrix} \end{array}$$

Extra #5

Constraints - multinomial additive hazards model

- $\sum_{j=0}^{c} Y_{ij} = 1$
- $\sum_{j=0}^{c} \pi_{ij} = 1$
- $\sum_{j=1}^{c} \pi_{ij} < 1$

Multinomial log-likelihood function

$$L(\beta) = \sum_{i=1}^{n} \left\{ \sum_{j=1}^{c} y_{ij} \log(\pi_{ij}) + (1 - \sum_{j=1}^{c} y_{ij}) \log(1 - \sum_{j=1}^{c} \pi_{ij}) \right\}$$

Extra #6

Variance-covariance matrix

- $j = j$

$$-\frac{\partial^2 L(\beta)}{\partial\beta_{jk}\partial\beta_{jk'}} = -\sum_{i=1}^{n} x_{ik}x_{ik'} \left\{ (\sum_{j=1}^{c} y_{ij}) \left[\frac{1}{(\sum_{j=1}^{c}\eta_{ij})^2} - \frac{\exp(-\sum_{j=1}^{c}\eta_{ij})}{[1-\exp(-\sum_{j=1}^{c}\eta_{ij})]^2} \right] - \frac{y_{ij}}{(\eta_{ij})^2} \right\}$$

- $j \neq j'$

$$-\frac{\partial^2 L(\beta)}{\partial\beta_{jk}\partial\beta_{jk'}} = -\sum_{i=1}^{n} x_{ik}x_{ik'} \left\{ (\sum_{j=1}^{c} y_{ij}) \left[\frac{1}{(\sum_{j=1}^{c}\eta_{ij})^2} - \frac{\exp(-\sum_{j=1}^{c}\eta_{ij})}{[1-\exp(-\sum_{j=1}^{c}\eta_{ij})]^2} \right] \right\}$$

Extra #7

Contribution of diseases to the disability prevalence

1. Cause-specific disability probability

$$B_{ij} = \frac{\alpha_{aj}}{\eta_{ij}} \cdot \pi_{ij}$$

$$D_{dij} = \frac{\beta_{adj}(X_{di} X_{ai})}{\eta_{ji}} \cdot \pi_{ij}$$

- B_i: probability of individual i being disabled by background
- D_{di}: probability of individual i being disabled by disease d

Extra #8

Contribution of diseases to the disability prevalence (Cont.)

2. Number of disabled individuals by cause

$$N_{bj} = \sum_{i=1}^{N} B_{ij}$$

$$N_{dj} = \sum_{i=1}^{N} D_{dij}$$

3. Prevalence of disability by cause

$$\text{Prev}_{bj} = \frac{N_{bj}}{N}$$

$$\text{Prev}_{dj} = \frac{N_{dj}}{N}$$

Extra #9

Competing hazards: general principle

- Comparison of disability in similar persons who only differ with respect to the presence/absence of disease
- **Belgian men aged 65-74 years with respiratory and/or back pain and mild disability**
  1. No disease → Background
  2. **Only** Respiratory → Background + Respiratory
  3. **Only** Back pain → Background + Back pain
  4. Both diseases → Background + Respiratory + Back pain
- Competing hazards of disability in groups 2-4: number of persons disabled from one cause depends on the hazard of multiple causes

Extra #10

Multimorbidity in the attribution method

- Background
  - $\alpha_{Mild,65-74y,Men,Be} = 0.02$
  - $\alpha_{Sev,65-74y,Men,Be} = 0.03$
- Respiratory
  - $\beta_{Respiratory,Mild,65-74y,Men,Be} = 0.31$
  - $\beta_{Respiratory,Sev,65-74y,Men,Be} = 0.13$
- Back pain
  - $\beta_{Back,Mild,65-74y,Men,Be} = 0.11$
  - $\beta_{Back,Sev,65-74y,Men,Be} = 0.02$

$$\eta_{i,Mild} = \alpha_{65-74y,Mild} + \beta_{Respiratory,Mild,65-74y,Men,Be} + \beta_{Back,Mild,65-74y,Men,Be}$$
$$\eta_{i,Sev} = \alpha_{65-74y,Sev} + \beta_{Respiratory,Sev,65-74y,Men,Be} + \beta_{Back,Sev,65-74y,Men,Be}$$

$$\eta_{i,Mild} = 0.02 + 0.31 + 0.11 = \mathbf{0.44}$$
$$\eta_{i,Severe} = 0.03 + 0.13 + 0.02 = \mathbf{0.18}$$

Extra #11

Cause-specific probabilities (B_{ij} and D_{dij})

$$\pi_{ij} = \left[1 - \exp(-\sum_{j=1}^{c} \eta_{ij})\right] \left(\frac{\eta_{ij}}{\sum_{j=1}^{c} \eta_{ij}}\right)$$

$$B_{ij} = \frac{\alpha_{aj}}{\eta_{ij}} \cdot \pi_{ij}$$

$$D_{dij} = \frac{\beta_{adj} X_{di} X_{ai}}{\eta_{ij}} \cdot \pi_{ij}$$

Men, Mild, 65-74y	α_{aj}	β_{Resp}	β_{Back}	η_{ij}	π_{ij}	B_{ij}	$D_{Resp,ij}$	$D_{Back,ij}$
No disease	0.02	0	0	0.02	0.01	**0.01**	0	0
Respiratory	0.02	0.31	0	0.33	0.25	**0.15**	0.23	0
Back pain	0.02	0	0.11	0.13	0.10	**0.15**	0	0.08
Respiratory & back pain	0.02	0.31	0.11	0.44	0.33	**0.15**	0.23	0.08

Why B_{ij} is different in the subgroups?