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

Renata Yokota
Wilma Nusselder, Jean-Marie Robine, Jean Tafforeau, Patrick Deboosere, Lenildo de Moura, Silvania Andrade, Herman Van Oyen

28th REVES Meeting, Vienna, 2016
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

Introduction

Extension of the attribution method to multinomial responses

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

---

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

<table>
<thead>
<tr>
<th></th>
<th>BRAZIL</th>
<th>BELGIUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>N = 60,202</td>
<td>N = 10,829</td>
</tr>
<tr>
<td>Response rate</td>
<td>77%</td>
<td>57%</td>
</tr>
<tr>
<td>Individuals ≥ 65 years</td>
<td>N = 7,123</td>
<td>N = 1,857</td>
</tr>
</tbody>
</table>

- 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

<table>
<thead>
<tr>
<th>Country</th>
<th>Question</th>
<th>Possible answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>Which degree of difficulty do you have to...?</td>
<td>1. No difficulty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Some difficulty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. A lot of difficulty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Unable</td>
</tr>
<tr>
<td>Belgium</td>
<td>Do you usually have difficulty in doing... by yourself?</td>
<td>1. No difficulty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Some difficulty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. A lot of difficulty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Cannot achieve by myself</td>
</tr>
</tbody>
</table>

- **Multinominal outcome:**
  - No disability (reference) = 1
  - Mild disability = 2
  - Severe disability = 3 or 4
Methods

Multinomial additive hazards model

\[ Y_{ij} \sim \text{Multinomial}(n_i, \pi_{ij}) \]

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

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

- \( Y_{ij} \): multinomial response variable (disability) for each individual \( i \)
- \( \pi_{ij} \): probability that individual \( i \) is disabled for each \( j \) category of the outcome
- \( \eta_{ij} \): total disability rate for each individual \( i \) for each \( j \) category of the outcome
- \( \alpha_{aj} \): background disability rate for each age group \( a \) (65-74 years; 75+ years) for each \( j \) category of the outcome
- \( \beta_{adj} \): 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
  \[ \eta_{ij} \geq 0 \]
  \[ \pi_{ij} = \left[ 1 - \exp\left( - \sum_{j=1}^{c} \eta_{ij} \right) \right] \left( \frac{\eta_{ij}}{\sum_{j=1}^{c} \eta_{ij}} \right) \]
- R package: addhaz
- Separate models for Brazil and Belgium
Results

Disease Prevalence

65–74 years

75 years +

Prevalence (%)
Results

Disability rates (disabling impacts)

Mild disability

Disability rate

Background

Diabetes
Heart
Stroke
Arthritis
Back pain
Depression
Respiratory

Brazil
Belgium

Men 65−74y
Men 75y+
Women 65−74y
Women 75y+

Severe disability

Disability rate

Brazil
Belgium

Men 65−74y
Men 75y+
Women 65−74y
Women 75y+
Results

Contribution to the disability prevalence - Women

- Background
- Diabetes
- Heart diseases
- Stroke
- Arthritis
- Back pain
- Depression
- Respiratory

Disability prevalence (%)
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

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Brazil</th>
<th>Belgium</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65-74 years</td>
<td>Stroke</td>
<td>Depression</td>
</tr>
<tr>
<td>≥75 years</td>
<td>Stroke</td>
<td>Respiratory</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65-74 years</td>
<td>Diabetes</td>
<td>Depression</td>
</tr>
<tr>
<td>≥75 years</td>
<td>Back pain</td>
<td>Arthritis</td>
</tr>
</tbody>
</table>
Thank you!
renata.yokota@wiv-isp.be
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
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
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:

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

<table>
<thead>
<tr>
<th>$i$</th>
<th>$Y_1$</th>
<th>$Y_2$</th>
<th>$Y_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i = 1$</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>$i = 2$</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>$\vdots$</td>
<td>$\vdots$</td>
<td>$\vdots$</td>
<td>$\vdots$</td>
</tr>
<tr>
<td>$i = n$</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
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

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

- **$j = j$**

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

- **$j \neq j'$**

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

1. Cause-specific disability probability

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

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

- \(B_{ij}\): probability of individual \(i\) being disabled by background
- \(D_{dij}\): 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

\[ \text{Prev}_{bj} = \frac{N_{bj}}{N} \]
\[ \text{Prev}_{dj} = \frac{N_{dj}}{N} \]
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**
  - $\beta_{Back, Mild, 65-74y, Men, Be} = 0.11$
  - $\beta_{Back, Sev, 65-74y, Men, Be} = 0.02$

\[
\eta_{i, Mild} = \alpha_{65-74y, Mild} + \beta_{Respiratory, Mild, 65-74y, Men, Be} + \beta_{Back, Mild, 65-74y, Men, Be}
\]
\[
\eta_{i, Sev} = \alpha_{65-74y, Sev} + \beta_{Respiratory, Sev, 65-74y, Men, Be} + \beta_{Back, Sev, 65-74y, Men, Be}
\]
\[
\eta_{i, Mild} = 0.02 + 0.31 + 0.11 = 0.44
\]
\[
\eta_{i, Severe} = 0.03 + 0.13 + 0.02 = 0.18
\]
Cause-specific probabilities ($B_{ij}$ and $D_{dij}$)

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

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

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

<table>
<thead>
<tr>
<th></th>
<th>$\alpha_{aj}$</th>
<th>$\beta_{Resp}$</th>
<th>$\beta_{Back}$</th>
<th>$\eta_{ij}$</th>
<th>$\pi_{ij}$</th>
<th>$B_{ij}$</th>
<th>$D_{Resp,ij}$</th>
<th>$D_{Back,ij}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>No disease</td>
<td>0.02</td>
<td>0</td>
<td>0</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Respiratory</td>
<td>0.02</td>
<td>0.31</td>
<td>0</td>
<td>0.33</td>
<td>0.25</td>
<td>0.15</td>
<td>0.23</td>
<td>0</td>
</tr>
<tr>
<td>Back pain</td>
<td>0.02</td>
<td>0</td>
<td>0.11</td>
<td>0.13</td>
<td>0.10</td>
<td>0.15</td>
<td>0</td>
<td>0.08</td>
</tr>
<tr>
<td>Respiratory &amp; back pain</td>
<td>0.02</td>
<td>0.31</td>
<td>0.11</td>
<td>0.44</td>
<td>0.33</td>
<td>0.15</td>
<td>0.23</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Why $B_{ij}$ is different in the subgroups?