Cause-of-death diversity from a multiple-cause perspective in the US

SEMinario in Scienze Economiche e Sociali
Università di Foggia

12 April 2023

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Background: Mortality measures

**Life expectancy:**
Expected average of length of life if a given set of mortality conditions were held fixed.

**Lifespan inequality:**
Measure the variability in ages at death.

But... what about **causes of death**?
Cause-of-death diversity

Measures the extent to which individuals die from a more similar or dissimilar variety of causes of death (Iszak 1986)

Cause-of-death diversity is a meaningful population health heterogeneity indicator:
- Micro-level: Diagnosis/treatment
- Macro-level: Mortality dynamics and health planning

Very little research on cause-of-death diversity (Bergeron-Boucher et al. 2020)

Clear increases in cause-of-death diversity over time in low-mortality countries.
**Background: Multiple Causes Of Death (MCOD)**

Most mortality studies use underlying causes of death (**UCOD**), i.e. the cause that initiated the sequence of events leading to death.

1. Ageing populations and raising multi-morbidity (King et al. 2018)
2. Growing complexity in underlying cause of death assignation (see Flagg & Anderson 2021)

Death certificates allow the inclusion of several causes of death.
**Background: Multiple Causes Of Death (MCOD)**

Most mortality studies use underlying causes of death (UCOD), i.e. the cause that initiated the sequence of events leading to death

1. Ageing populations and raising multi-morbidity (King et al. 2018)
2. Growing complexity in underlying cause of death assignation (see Flagg & Anderson 2021)

Three main ways to contribute to death in relation to the underlying cause of death:
1. Consequence or complication
2. A consequence of the therapy
3. A risk factor or background factor

<table>
<thead>
<tr>
<th>Cause of death</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disease or condition directly leading to death*</td>
</tr>
<tr>
<td>(a) .........................</td>
</tr>
<tr>
<td>due to (or as a consequence of)</td>
</tr>
</tbody>
</table>

| Antecedent causes |
| Morbid conditions, if any, giving rise to the above cause, stating the underlying condition last |
| (b) ......................... |
| due to (or as a consequence of) |
| (c) ......................... |
| due to (or as a consequence of) |
| (d) ......................... |

| Other significant conditions contributing to the death, but not related to the disease or condition causing it |
| .......................... |

*This does not mean the mode of dying, e.g. heart failure, respiratory failure. It means the disease, injury, or complication that caused death.
**Example: Hypothetical death certificate**

**INTERNATIONAL FORM OF MEDICAL CERTIFICATE OF CAUSE OF DEATH**

<table>
<thead>
<tr>
<th>Cause of death</th>
<th>Approximate interval between onset and death</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Disease or condition directly leading to death*</td>
<td></td>
</tr>
<tr>
<td>Antecedent causes</td>
<td></td>
</tr>
<tr>
<td>Morbid conditions, if any, giving rise to the above cause, stating the underlying condition last</td>
<td></td>
</tr>
<tr>
<td>(a) Diseases of the blood</td>
<td></td>
</tr>
<tr>
<td>due to (or as a consequence of)</td>
<td></td>
</tr>
<tr>
<td>Infectious disease</td>
<td></td>
</tr>
<tr>
<td>(b)</td>
<td></td>
</tr>
<tr>
<td>due to (or as a consequence of)</td>
<td></td>
</tr>
<tr>
<td>(c)</td>
<td></td>
</tr>
<tr>
<td>due to (or as a consequence of)</td>
<td></td>
</tr>
<tr>
<td>(d) Any cancer</td>
<td></td>
</tr>
<tr>
<td><strong>Hypertension, Obesity</strong></td>
<td></td>
</tr>
</tbody>
</table>

*This does not mean the mode of dying, e.g. heart failure, respiratory failure. It means the disease, injury, or complication that caused death.*
Background: Mortality dynamics in the US

The US, a singular case of study: life expectancy lagging behind, decelerated and stagnated

Life expectancy at birth trends, US and other low-mortality countries

Ho et al. 2018 BMJ
Background: Mortality dynamics in the US

The US, a singular case of study

Lifespan variation trends, US and other low-mortality countries

Bergeron-Boucher et al. 2020, BMJ Global Health
Aim

We aim to examine cause-of-death diversity in the US by developing and applying a new approach based on the analysis of multiple causes of death by age groups, sex, and educational attainment over the period 2003-2018.
Data & Methods
## Data

### Individual-level multiple causes of death data for 2003-18 for the US from the Centers for Disease Control and Prevention

### Deaths aged ≥ 30 years of age

### Education (completed years):
- 0-11 years (low)
- 12 (high)
- 13+ (some college or higher)

<table>
<thead>
<tr>
<th>Group of causes</th>
<th>International Classification of Diseases - 10 codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infectious</td>
<td>A00-B99</td>
</tr>
<tr>
<td>Neoplasms</td>
<td>C00-D48</td>
</tr>
<tr>
<td>Metabolic</td>
<td>E00-E88</td>
</tr>
<tr>
<td>Mental</td>
<td>F01-F99</td>
</tr>
<tr>
<td>Nervous</td>
<td>G00-G98</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>I00-I99</td>
</tr>
<tr>
<td>Respiratory</td>
<td>J00-J98</td>
</tr>
<tr>
<td>Digestive</td>
<td>K00-K92</td>
</tr>
<tr>
<td>Musculoskeletal</td>
<td>M00-M99</td>
</tr>
<tr>
<td>Genitourinary</td>
<td>N00-N98</td>
</tr>
<tr>
<td>Ill-defined</td>
<td>R00-R99</td>
</tr>
<tr>
<td>External causes</td>
<td>S00-Y89</td>
</tr>
<tr>
<td>Other causes</td>
<td>D50-D89, H00-H93, L00-L98, O00-O99, P00-P96, Q00-Q99</td>
</tr>
</tbody>
</table>
Step 0. Decide the degree to which underlying causes are more important than the other causes listed in the death certificate by assigning weights for underlying ($W$) and contributory causes ($\omega$):

$$W + 12\omega = 1$$

Thus, fixing $W$:

$$\omega = \frac{1 - W}{12}$$

Therefore $W$ should range between $1/13$ and $1$

We estimate our results for the following $W$ values: $1/13$, 0.2, 0.5, and 1
Methods (II)

Step 1. Define distances (**degree of (dis)similarity**) between all pairs of sets of causes of death

\[ d((a; i), (b; j)) = \sum_{k=1}^{13} |w_{i,k}a_k - w_{j,k}b_k| \]

Examples:

A. **CVD & Metabolic**

B. **Respiratory, CVD & Metabolic**

C. **External**

\[ \frac{1}{13} < W < 1 \]

UCOD

MCOD
Step 2. Average the distances estimates across pairs of sets of causes accounting for their adjusted prevalence

\[ D = \sum_{(a; i) \in \Omega} \sum_{(b; j) \in \Omega} p_{(a, i)}^* p_{(b, j)}^* d((a; i), (b; j)) \]

\( p_{(a, i)}^* \) is the life-table adjusted share of death certificates having \((a; i)\) as the set of causes

We normalized the results using 2003 as baseline \(D_{2003}=1\) for any given \(W\).
Methods (IV)

\( D \) is decomposable into between and within group (education) components

\[
D = \sum_{g=1}^{G} p_g^2 D_g + \sum_{g=1}^{G-1} \sum_{h=g+1}^{G} 2p_g p_h D_{gh}
\]

The role of the changing composition of the population. Following Kitgawa’s decomposition (1964):

\[
\Delta D = D_2 - D_1 = f(p_2, D_2) - f(p_1, D_1) = \Delta_p + \Delta_D
\]

\[
\Delta_p = \frac{[f(p_2, D_2) - f(p_1, D_2) + f(p_2, D_1) - f(p_1, D_1)]}{2}
\]

\[
\Delta_D = \frac{[(f(p_2, D_2) - f(p_2, D_1)) + (f(p_1, D_2) - f(p_1, D_1))]}{2}
\]
Results
Results (I): Combinations of causes of death, men, 2018

Mentions in death certificates
Results (II): Trends in normalized cause-of-death diversity

$W$ represents the importance of the underlying versus other causes of death.
Results (III): Trends in normalized cause-of-death diversity by age groups

$W$ represents the importance of the underlying versus other causes of death
Results (IV): Trends in normalized cause-of-death diversity by educational attainment ($W = 0.5$)
Results (V): Trends in normalized cause-of-death diversity by educational attainment ($\mathcal{W} = 0.5$) and age groups
Results (VI): Decomposition of cause-of-death diversity increases between (2003-18) between dynamics of between-educational group and within educational group contributions at ages 30 and over, US
Discussion
Discussion

Cause-of-death has been increasing over the last 2 decades, in line with a previous study (Bergeron-Boucher et al. 2020)

Increases in cause-of-death diversity are larger when MCOD are accounted for -> Efforts to reduce mortality should be divided within larger groups of causes (*Multi-morbidity*)

Clear and increasing **educational gradients**:  
Highest educated -> lower cause-of-death diversity

Relationship between cause-of-death diversity and other mortality indicators is not straightforward
Strengths and limitations

We relied on MCOD data. Changes in coding practices could not be controlled for.

Conservative cause-of-death grouping in 13 main ICD groups.

Diversity indicator is dependent on the cause-of-death grouping.

Diversity indicator based on an adaptation of the Fractionalization index (Alessina et al. 2003), and highly correlated with other indices measuring diversity (Davydov and Weber 2016).

The measurement of distances between (groups of) causes of death.
Conclusion

Cause-of-death diversity provides valuable information on the variability of groups of causes to be tackled.

The use of MCOD brings multi-morbidity at death in the mortality debate.

Cause-of-death diversity can complement currently existing approaches measuring population health inequalities.

Further research is needed to further disentangle the role of specific sets of cause-of-death.
Grazie per l’attenzione

Link to the full paper

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Cause-of-death diversity


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Cause-of-Death Diversity From a Global Perspective in the United States

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Júlia Almeida Calazans\textsuperscript{1} and Iñaki Permanyer\textsuperscript{1,2,*}


Cause-of-death diversity

Measures the extent to which individuals die from a more similar or dissimilar variety of causes of death (Izak 1986)

One publication (Bergeron-Boucher et al. 2020)

Clear increases in cause-of-death diversity over time

Cause-of-death variation for 15 low-mortality countries, 1997-2017

Bergeron-Boucher et al. 2020, BMJ Global Health
Results (VII): Decomposition of cause-of-death diversity increases (2003-18)