Cause of Death Mortality: International Trends by Socio-Economic Group

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Joint work with C. Redondo, D. Blake, K. Dowd, M. Kallestrup-Lamb, C. Rosenskjold

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Outline

- Motivation and long term goals
- Data
- Comparison of US, Denmark and England
- England: deeper dive
Purpose of looking at cause of death data

- What are the key drivers of all-cause mortality?
- How are the key drivers changing over time?
- Which causes of death have high levels of inequality:
  - by education;
  - by affluence;
  - deprivation?
- Can we point to specific causes of death as responsible for growing inequality?
- Leading to: insight into mortality underpinning life insurance and pensions
Drivers

Medical advances →

- Public health initiatives → ?? period effects
- Health spending by age →

- Individual risk factors:
  - Controllable (Cancer UK: *preventable*)
    e.g. smoking, diet, exercise, alcohol, sun, drugs, hygiene, risky sex, stress, environment...

    leading to cohort effects
  - Not (easily) controllable
    e.g. genetic, affluence, education, character/personality traits, ...
Socio-economic datasets

Cause of death data for:
- US (males and females)
  - by education level: low (≤ high school); high (≥ some college)
- Denmark (males only):
  - by education level: low (< high sch.); medium (=high sch.); high (≥ some college) (cohorts > 1920 only)
  - by individual affluence: 10 deciles
- England (males and females)
  - by small area income deprivation: 10 deciles
  - by region: 9 areas
## Cause of Death Groupings

<table>
<thead>
<tr>
<th>US1.1</th>
<th>Infectious diseases excl. HIV/AIDS</th>
<th>US 1.2</th>
<th>HIV/AIDS</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Infectious diseases</td>
<td>2</td>
<td>Cancer: mouth, gullet, stomach</td>
</tr>
<tr>
<td>3</td>
<td>Cancer: gut, rectum</td>
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<td>Cancer: larynx</td>
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<tr>
<td>4.2</td>
<td>Cancer: trachea</td>
<td>4.3</td>
<td>Cancer: lung, bronchus</td>
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<tr>
<td>5</td>
<td>Cancer: breast</td>
<td>6.1</td>
<td>Cancer: uterus, cervix</td>
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<tr>
<td>6.2</td>
<td>Cancer: ovary</td>
<td>6.3</td>
<td>Cancer: other female genital</td>
</tr>
<tr>
<td>7.1</td>
<td>Cancer: prostate, testicular</td>
<td>7.2</td>
<td>Cancer: other male genital</td>
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<tr>
<td>8</td>
<td>Cancer: skin, bones and certain organs</td>
<td>9</td>
<td>Cancer: lymphatic</td>
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<td>Benign tumours</td>
<td>11</td>
<td>Diseases: blood</td>
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<td>12</td>
<td>Diabetes</td>
<td>13</td>
<td>Mental illness</td>
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<td>14.1</td>
<td>Diseases of nervous system excl. Alzh.</td>
<td>14.2</td>
<td>Alzheimers</td>
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<tr>
<td>15</td>
<td>Blood pressure + rheumatic fever</td>
<td>16</td>
<td>Ischaemic heart diseases</td>
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<tr>
<td>17</td>
<td>Other heart diseases</td>
<td>18</td>
<td>Diseases: cerebrovascular</td>
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<td>19</td>
<td>Diseases: circulatory</td>
<td>20</td>
<td>Diseases: lungs, breathing</td>
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<tr>
<td>21</td>
<td>Diseases: digestive (excl. alcohol: 27)</td>
<td>22</td>
<td>Diseases: urine, kidney,...</td>
</tr>
<tr>
<td>23</td>
<td>Diseases: skin, bone, tissue</td>
<td>24(DU)</td>
<td>Senility without mental illness</td>
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<td>25</td>
<td>Road/other accidents</td>
<td>26</td>
<td>Other causes</td>
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<td>27</td>
<td>Alcohol → liver disease</td>
<td>28</td>
<td>Suicide</td>
</tr>
<tr>
<td>29</td>
<td>Accidental Poisonings</td>
<td></td>
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</tbody>
</table>

Colours ⇒ broad CoD groups (e.g. cancers)
Detail ⇒ able to separate causes with and without significant risk factors or inequality
Data – Other Details

- **US**
  - Deaths subdivided into 30 CoD groups
  - Single ages 40-89 and *born between 1914 and 1970*
  - Single years 1989-2015

- **Denmark**
  - 29 CoD groups
  - Age groups 31-35, 36-40, ..., 91-95

- **England**
  - 34 CoD groups
  - Age groups 20-24, 25-29, ..., 85-89
  - Single years 2001-2016
England – Deprivation – Top 10 CoD

Males; Ages 70-74; Year 2016

<table>
<thead>
<tr>
<th>Rank</th>
<th>Most Deprived</th>
<th>Least Deprived</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Respiratory</td>
<td>Skin &amp; organ cancer</td>
</tr>
<tr>
<td>2</td>
<td>Ischaemic heart</td>
<td>Ischaemic heart</td>
</tr>
<tr>
<td>3</td>
<td>Lung cancer etc.</td>
<td>Respiratory</td>
</tr>
<tr>
<td>4</td>
<td>Skin &amp; organ cancer</td>
<td>Lung cancer etc.</td>
</tr>
<tr>
<td>5</td>
<td>Cerebrovascular</td>
<td>Prostate cancer</td>
</tr>
<tr>
<td>6</td>
<td>Oesoph., stom. cancer</td>
<td>Cancer: lymphatic, myeloma, etc.</td>
</tr>
<tr>
<td>7</td>
<td>Bowel, gut cancer</td>
<td>Nervous system excl. Alzh.</td>
</tr>
<tr>
<td>8</td>
<td>Other heart dis.</td>
<td>Cerebrovascular</td>
</tr>
<tr>
<td>9</td>
<td>Digestive diseases</td>
<td>Oesoph., stom. cancer</td>
</tr>
<tr>
<td>10</td>
<td>Prostate cancer</td>
<td>Bowel, gut cancer</td>
</tr>
</tbody>
</table>

No controllable risk factors: e.g. Prostate – almost no inequality.

Significant controllable risk factors feature much more heavily amongst the most deprived.
England – Deprivation – Top 10 CoD

Females; Ages 70-74; Year 2016

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</tr>
<tr>
<td>10</td>
<td>Mental illnesses</td>
<td>Ovarian cancer</td>
</tr>
</tbody>
</table>

No controllable risk factors: e.g. Breast and other cancers

Significant controllable risk factors feature much more heavily amongst the most deprived.
Multi-Country Comparisons

- Up to 34 causes of death
- Many very low death rates or not so interesting
- Here: a few of the more interesting cases
  - Major CoD’s
  - Widening gap
  - Unexpected regional effects
  - Story to tell that might apply to other CoD’s
Impact of Controllable Risk Factors

- Risk factors (controllable and not controllable) ⇒
  Impact on cause of death rates

- Some risk factors ⇒ big impact on some causes
  e.g. smoking → lung cancer
  e.g. several risk factors → ischaemic heart disease
  ⇒ significant inequality gaps

- Other causes of death:
  no known (significant) controllable risk factors
  e.g. prostate cancer, breast cancer
US By Education 2007
Ischaemic heart diseases

Death Rate (log scale)

US By Education 2007
Ischaemic heart diseases

Death Rate (log scale)

Danmark By Education 2007
Ischaemic heart diseases

Death Rate (log scale)

England by Deprivation 2007
Ischaemic heart diseases

Death Rate (log scale)

US: slightly wider than Denmark

England similar to Denmark but higher
Multi-Country: Age 68, Males, Ischaemic Heart Disease

Significant improvements, but not throughout
Multi-Country: Age 68, Males, Lung Cancer

Significant inequality; improvements might be driven by smoking prevalence
Multi-Country: Age 68, Females, Lung Cancer

US by Education, Age 68
Cancer: lung, larynx, ..

England by Deprivation, Age 68
Cancer: lungs, bronchus

Significant inequality; deterioration mainly driven by smoking prevalence
Impact of Controllable Risk Factors

- Risk factors (controllable and not controllable)
  ⇒ Impact on cause of death rates
- Some risk factors ⇒ big impact on some causes
  e.g. smoking → lung cancer
  e.g. several risk factors → ischaemic heart disease
  ⇒ significant inequality gaps
- Other causes of death:
  *no known (significant) controllable risk factors*
  e.g. prostate cancer, breast cancer
No controllable risk factors; US inequalities; England equality (?)
Variation in Reporting Practice: e.g. Mental Illness

**US By Education 2007**
Mental Illness

**Denmark By Education 2007**
Mental Illness

**Denmark By Affluence 2007**
Mental Illness

**England by Deprivation 2007**
Mental Illnesses

Alcohol & drug abuse; mental disorders; \(\rightarrow\) vascular dementia
Multiple CoD + Reporting practice (??) \(\Rightarrow\) DK \(>>\) US \(>>\) Eng.
Variation in Reporting Practice: e.g. Mental Illness

Alcohol & drug abuse; mental disorders; \(\rightarrow\) vascular dementia
Multiple CoD + Reporting practice (??) \(\Rightarrow\) DK >> US >> Eng.
E.g. accidental drug overdoses

“Deaths of Despair”: Case and Deaton (2015)

**US By Education 2012**
Accidental Poisonings

**Denmark By Education 2012**
Accidental Poisonings

**Denmark By Affluence 2012**
Accidental Poisonings

**England by Deprivation 2012**
Accidental poisonings

Growth: England > US > DK

US: evidence of a cohort effect

US By Education 2002
Alcohol induced liver disease

Denmark By Education 2002
Alcohol induced liver disease

Denmark By Affluence 2002
Alcohol induced liver disease

England by Deprivation 2002
Alcohol related liver disease

Affluence a much bigger driver

US By Education 2012
Alcohol induced liver disease

Denmark By Education 2012
Alcohol induced liver disease

Denmark By Affluence 2012
Alcohol induced liver disease

England by Deprivation 2012
Alcohol related liver disease

US: possible cohort effect

2002-12: No significant growth

Denmark: education level data not currently available for this period
England: Deeper Dive

Compare

- Income deprivation deciles
- 9 English regions
England: Income Deprivation versus Region

North East
North West
Yorkshire & Humber
East Midlands
West Midlands
East of England
London
South East
South West

Not in dataset:
Scotland, Wales, Northern Ireland
Age (& Deprivation) Standardised Mortality Rate

(CoD) Death rates: \( m(x) \), \( m_l(i, x) \), \( m_R(r, x) \), \( m_{Rl}(r, i, x) \)

\[
\text{ASMR} = \frac{\sum_x m(x) \cdot ES(x)}{\sum_x ES(x)}
\]

where \( ES(x) \) = “standard” population

Variants:

\[
\text{ASMR}_I(i) = \frac{\sum_x m_l(i, x) \cdot ES(x)}{\sum_x ES(x)} \quad \text{(income decile)}
\]

\[
\text{ASMR}_R(r) = \frac{\sum_x m_R(r, x) \cdot ES(x)}{\sum_x ES(x)} \quad \text{(region)}
\]

\[
\text{ASMR}_{Rl}(r, i) = \frac{\sum_x m_{Rl}(r, i, x) \cdot ES(x)}{\sum_x ES(x)} \quad \text{(region, income)}
\]

\[
\text{ADSMR}_R(r) = \frac{1}{10} \sum_i \text{ASMR}_{Rl}(r, i)
\]

ADSMR adjusts for different income deprivation mix by region
Income deprivation deciles: widening gap
Clear “London Effect”.
Greater improvements in healthcare??
Greater improvements in GDP??
Educational attainment rising faster?? (immigration??)
Males and females: significant regional effects remain after accounting for income deprivation (All cause data: other non-regional covariates being investigated)
Lung Cancer: Males

Significant variation between income deciles (⇒ smoking prevalence)
Significant variation between regions (after standardisation)
×1.5 variation by region; ×2.5 by income decile
London effect; Northern regions very poor
Lung Cancer: Females

Slight worsening ⇒ ?? smoking prevalence rising
Same northern regions do badly
Wider regional spread
London effect
Respiratory Diseases: Males

Flatter than males: similar pattern to lung cancer males
Respiratory Diseases: Females

Similar pattern to lung cancer females
Weaker improvements than males linked to smoking prevalence, especially high deprivation.
Success story: major improvements
Less good: widening gap and regional inequality
Females: similar picture
A Broad Observation

As the impact of a *controllable* risk factor on a particular CoD increases we observe:

- greater inequality in the corresponding CoD death rates
  - by income deprivation
  - by region
  - by region even after adjusting for differing levels of income deprivation

Possible sources of the region effect:

- Other socio-economic variables?
  - E.g. education levels within each income deprivation decile
- Greater deprivation on average across the region leads to generally poorer health behaviour?
- ???
Limited controllable risk factors

“Success story”: no significant income or regional inequality (including ?? diagnosis)
Limited controllable risk factors
Limited income effect
Significant regional effect
Prostate Cancer: A Small London Effect?

England Males ADSMR By Region
Cancer: prostate

England Males ASMR By Income
Cancer: prostate
Diabetes: Males

Significant inequality
Widening inequality gap by income deciles
Worsening mortality after about 2010
Alzheimers: Females (no clear controllable risk factors)

Modest income effect

Strong regional effect $\Rightarrow$ ?? health migration
Alzheimers: Females (no clear controllable risk factors)

Deterioration \(2 \times \) \(\Rightarrow \) ??

- evidence for non-independence of causes of death improvements elsewhere
  \(\Rightarrow \) ?? more frail survivors in old age
- gradual shift in reported cause of death
Shifting Classification 2010-2011: Mental Illness

Cause of shift: doubling in vascular and other dementias as CoD
(Additional source: Human Cause of Death Database (HCD))
E.g. stroke ↔ vascular dementia
(Additional source: Human Cause of Death Database (HCD))
Shifting Classification 2010-2011: Other Heart Diseases

**England Males ADSMR By Region**

Other heart diseases

**England Males ASMR By Income**

Other heart diseases

Pulmonary heart diseases; heart failure ↘↘ after 2011
(Additional source: Human Cause of Death Database (HCD))
Shifting Classification 2010-2011: Genitourinary Diseases

England Males ADSMR By Region
Urine, kidney, genital organs, and breast gland diseases

England Males ASMR By Income
Urine, kidney, genital organs, and breast gland diseases

N39: Urinary tract infection (Additional source: Human Cause of Death Database (HCD))
Which Causes of Death $\Rightarrow$ Growing Inequality?

- Ischaemic heart disease
- Diabetes
- Cerebrovascular
- Circulatory
- Respiratory diseases
- Mental illnesses (females)
- Lung cancer

$\Rightarrow$ a widening gap in the prevalence of controllable risk factors: smoking, diet, exercise, alcohol etc.

no significant causes of death with narrowing inequality gap
Many Questions Remain

- Is it possible to decompose improvements into medical advances and changes in risk “taking”?  
- E.g. Can we link smoking prevalence to e.g. lung cancer mortality?  
- What are the causes of the London Effect?
Summary

- Affluence or income deprivation is better than education for all CoD if you have the data
- Impact of affluence/education/region varies with CoD
- Significant levels of inequality for most of the big CoD’s
- CoD *absolute levels* vary between countries: local practice (?)
- But *degree of inequality* by CoD is consistent from country to country
- Second order differences between countries may be due to healthcare systems
- England:
  - Regional differences in addition to income effects
  - Consistent patterns by CoD connected to *controllable* risk factors
Appendix to these slides: lots more on the English data
Work in progress: reports and papers in 2019
Some related presentations already online
Follow us at:

www.macs.hw.ac.uk/~andrewc/ARCresources
www.actuaries.org.uk/ARC
Thank You!

Questions?

E: A.J.G.Cairns@hw.ac.uk

W: www.macs.hw.ac.uk/~andrewc/ARCresources
The Actuarial Research Centre (ARC) is the Institute and Faculty of Actuaries’ (IFoA) network of actuarial researchers around the world. The ARC seeks to deliver cutting-edge research programmes that address some of the significant, global challenges in actuarial science, through a partnership of the actuarial profession, the academic community and practitioners.

The 'Modelling, Measurement and Management of Longevity and Morbidity Risk' research programme is being funded by the ARC, the SoA and the CIA.

[www.actuaries.org.uk/arc](http://www.actuaries.org.uk/arc)
Appendix

England
Income and Regional cause of death plots in full.
England Females ADSMR By Region
Infectious diseases (including TB and HIV/AIDS)

England Females ASMR By Income
Infectious diseases (including TB and HIV/AIDS)
Appendix

England Males ADSMR By Region
Cancer: oesophagus, stomach

England Males ASMR By Income
Cancer: oesophagus, stomach

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Appendix

England Females ADSMR By Region
Cancer: oesophagus, stomach

England Females ASMR By Income
Cancer: oesophagus, stomach
Appendix

**England Males ADSMR By Region**

*Cancer: larynx*

**England Males ASMR By Income**

*Cancer: larynx*

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England Females ADSMR By Region
Cancer: breast

England Females ASMR By Income
Cancer: breast

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Appendix

England Females ADSMR By Region
Cancer: uterus, cervix

England Females ASMR By Income
Cancer: uterus, cervix

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Cause of Death Mortality
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Appendix
Appendix

England Females ADSMR By Region
Benign tumours

England Females ASMR By Income
Benign tumours
Appendix

**England Males ADSMR By Region**
Diseases in blood and blood–forming organs, as well as endocrine sufferings and deficiency diseases

**England Males ASMR By Income**
Diseases in blood and blood–forming organs, as well as endocrine sufferings and deficiency diseases

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England Females ADSMR By Region
Diabetes

England Females ASMR By Income
Diabetes

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Appendix

England Females ADSMR By Region
Diseases of nervous system as well as sense organs, excl. Alzheimers

England Females ASMR By Income
Diseases of nervous system as well as sense organs, excl. Alzheimers
England Males ADSMR By Region
Alzheimers

England Males ASMR By Income
Alzheimers

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England Females ADSMR By Region
Alzheimers

England Females ASMR By Income
Alzheimers

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England Males ADSMR By Region
Increased blood pressure or rheumatic fever

England Males ASMR By Income
Increased blood pressure or rheumatic fever

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Appendix

England Females ADSMR By Region
Increased blood pressure or rheumatic fever

England Females ASMR By Income
Increased blood pressure or rheumatic fever

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Appendix

England Males ADSMR By Region
Ischaemic heart diseases

England Males ASMR By Income
Ischaemic heart diseases

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## Appendix

### England Males ADSMR By Region

**Cerebrovascular diseases**

<table>
<thead>
<tr>
<th>Year</th>
<th>2000</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
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<td>North West</td>
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<tr>
<td>Yorkshire and The Humber</td>
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<tr>
<td>East Midlands</td>
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<tr>
<td>West Midlands</td>
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<tr>
<td>East of England</td>
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<td>London</td>
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<td>South East</td>
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### England Males ASMR By Income

**Cerebrovascular diseases**

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<tr>
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England Males ADSMR By Region
Circulatory diseases

England Males ASMR By Income
Circulatory diseases

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Cause of Death Mortality
Appendix

England Females ADSMR By Region
Circulatory diseases

England Females ASMR By Income
Circulatory diseases

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Appendix

England Females ADSMR By Region
Digestive diseases excluding alcohol liver disease and cirrhosis

England Females ASMR By Income
Digestive diseases excluding alcohol liver disease and cirrhosis

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England Females ADSMR By Region
Alcohol related liver disease

England Females ASMR By Income
Alcohol related liver disease

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England Males ADSMR By Region
Urine, kidney, genital organs, and breast gland diseases

England Males ASMR By Income
Urine, kidney, genital organs, and breast gland diseases

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Cause of Death Mortality
England Females ADSMR By Region
Road and other accidents

Year
ADSMR (log scale)
North East
North West
Yorkshire and The Humber
East Midlands
West Midlands
East of England
London
South East
South West

England Females ASMR By Income
Road and other accidents

Year
ASMR (log scale)
1
2
3
4
5
6
7
8
9
10
Appendix

England Males ADSMR By Region
Other causes of death

England Males ASMR By Income
Other causes of death

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Cause of Death Mortality
Appendix

England Females ADSMR By Region

Suicide

England Females ASMR By Income

Suicide

Andrew J.G. Cairns

Cause of Death Mortality
Appendix

England Females ADSMR By Region
Accidental poisonings

England Females ASMR By Income
Accidental poisonings