Use of Big Health and Actuarial Data for understanding Longevity and Morbidity

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Quantifying longevity and morbidity changes

• Medical and social advances are the major drivers of longevity and morbidity changes. But how to quantify these relationships?
• In medicine, Randomized Control Trials (RCTs) are considered to be the gold standard.
• RCTs estimate the hazard or force of mortality in a (selective) sample of people and summarised over the observed (limited) time period.
• New health interventions are usually based on these estimated hazards obtained from clinical trials. A lengthy lead time would be needed to observe their effect on population longevity.
Individual level data

• Our research uses The Health Improvement Network (THIN) primary care data to develop statistical models of longevity and morbidity.

• The advantage of using individual level medical data is that it is possible to model both the uptake of medical treatment and the effect of that treatment on longevity conditional on the individual sociodemographic and health factors instead of the aggregated profile.

• Survival models, usually the Cox’s regression, are fitted to individual level data.

• The conclusions are generalisable to the general population.
The Health Improvement Network (THIN) data

- Anonymised electronic primary care medical records (Vision)
- Data collection began in 2003 using Read codes
- 11 million patients, 3.7 million active patients
- 562 general practices, covering 6.2% of the UK population
- Diagnoses, prescriptions, consultations, postcode deprivation

Subset of THIN selected for our research:

- All patients born before 1960 and followed to 01.01.2017, this includes 3.5 million patients
- Social economic status variables such as Index of Multiple Deprivation (IMD), Townsend and Mosaic
- IMD: income, employment, health, education, crime, housing
- Townsend: employment, car ownership, home ownership, household overcrowding
- Mosaic: consumer classification based on demographics, lifestyles and behaviour of a person
Target conditions and interventions
Poll 1

What do you think are the main causes of the apparent slowdown in mortality improvements over that last few years? (You can select more than one answer.)

• Diet/Lifestyle factors (obesity epidemic, substance abuse, etc.)
• Austerity (insufficient health/social care spending)
• Extreme weather (cold winters/hot summers)
• Antibiotic resistance
• Flu strains
• Previous drivers of improvements having run their course
• Other
Changes in individual and population life expectancy due to medical interventions

- We have developed methodology allowing to translate results from analyses of health care data, such as uptake of interventions and hazard ratios of death, into changes in individual and population life expectancy.

- For individuals, the hazard ratio of an intervention is translated into equivalent change in age using the Gompertz distribution [Brenner et al, 1993]. This is based on the definition of chronological and effective age [Spiegelhalter, 2016].

- This helps to explain consequences of conditions and lifestyle choices and can be used to nudge clients to pursue a healthier lifestyle.
Survival prospects associated with statin prescription and changes in effective age

Adjusted for sex, year of birth, socioeconomic status (Mosaic), diabetes, high cholesterol level, blood pressure regulating drugs, body mass index, smoking status, and general practice.

Change in effective age based on the UK life tables of 2010-12 (ONS, 2017).

<table>
<thead>
<tr>
<th>Age</th>
<th>QRISK2: 10-19%</th>
<th>QRISK2 ≥20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td>0.00</td>
<td>-1.51</td>
</tr>
<tr>
<td>70</td>
<td>-1.17</td>
<td>-1.86</td>
</tr>
<tr>
<td>75</td>
<td>-2.36</td>
<td>-1.99</td>
</tr>
</tbody>
</table>
Calculating an effect on population life expectancy (LE)

• Period life expectancy $e_x$ at age $x$ is a weighted average of component LEs, of people with different risk profiles, with the weights defined by the prevalence $p$ of the risk factor of interest and/or the uptake of relevant intervention.

• Splitting the overall LE into these components allows to estimate hypothetical changes in life expectancy at the population level at different scenarios.
## Period life expectancy for people with or without statin prescription

<table>
<thead>
<tr>
<th>Sex</th>
<th>Period life expectancy</th>
<th>Age 70 (95% CI)</th>
<th>Age 75 (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td>National</td>
<td>14.45</td>
<td>11.11</td>
</tr>
<tr>
<td></td>
<td>Prescription</td>
<td>15.14-15.17</td>
<td>11.79-11.81</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td>National</td>
<td>16.67</td>
<td>12.92</td>
</tr>
<tr>
<td></td>
<td>Prescription</td>
<td>17.34-17.36</td>
<td>13.86-13.87</td>
</tr>
<tr>
<td></td>
<td>No prescription</td>
<td>15.92-16.03</td>
<td>11.92-12.01</td>
</tr>
</tbody>
</table>

Note: statins prescription for both primary and secondary prevention of cardiovascular disease (CVD). Estimates of prevalence of CVD and survival benefits of statins given CVD are obtained from our previous published work (Gitsels et al, 2017).
Statins and increase in period life expectancy

• The increase in life expectancy from 1987 to 2010 in women was 2.7 and 2.2 years at ages 70 and 75 and in men 3.7 and 2.8 years at ages 70 and 75.

• Statins contributed to 72% (60-88%) of this increase in life expectancy at age 70 and to 54% (41-68%) of this increase at age 75.

• At 100% uptake, life expectancy of women aged 70 or 75 would be increased by 0.7 or 1.0 years; expectancy for men aged 70 or 75 would be increased by 0.8 years.
The views expressed in this presentation are those of the presenter.
Example 2: Would intensive systolic blood pressure control increase longevity?

- SPRINT trial reported considerable survival benefits of intensive systolic blood pressure (SBP) lowering below 120 mmHg.

- Adverse Renal Outcome was one of the main adverse effects, with the odds raised threefold in patients without Chronic Kidney Disease at baseline.

- The American Heart Association changed its hypertension guideline on the basis of SPRINT results (Whelton et al, 2017).

- The primary objective of our study was to investigate the survival benefits of intensive SBP lowering in UK primary care and to compare them to SPRINT results.
Study design

- The sample included 54,683 patients from THIN (50-90 yr) who were treated for hypertension between 2005 and 2013 and followed-up to 2017.

- Group 1: patients with SBP>140 mmHg (SBP1) which was lowered to less than 120 mmHg; 19,756 (36%) patients.

- Group 2: SBP>140 mmHg lowered to 120-140 mmHg; 34,927 (64%) patients.

- Time interval: 2 weeks to 6 months + new prescription.
Results (to appear in Journal of Hypertension)

• SPRINT: the intensive treatment had a hazard ratio (HR) of 0.73 (0.60, 0.90) compared to standard treatment:
  – a decrease in effective age of 3.4 to 3.6 years.
  – AHA Guidelines: boost to the life expectancy in the US?

• THIN: the intensive group had significantly increased HR of 1.35 (1.14, 1.27):
  – an increase in effective age of 1.7 to 1.8 years.

• In both studies, more than 2 blood pressure lowering drugs, and increase in dosage (THIN) further significantly increased the hazards of mortality and the hazard of adverse renal outcomes.
Poll 2

Thinking about the possible ‘stalling’ of mortality improvements, what would you expect life expectancies to do in the next 5-10 years?

• Start to decrease
• Remain level
• Increase more slowly than the 2000-2010 rate
• Increase at about the 2000-2010 rate
• Increase faster than the 2000-2010 rate
Data selected for other target conditions and interventions

Top 10 causes of death globally 2015

- Ischaemic he...
- Stroke
- Lower respira...
- Chronic obst...
- Trachea, bron...
- Diabetes mel...
- Alzheimer dis...
- Diarrheal di...
- Tuberculosis
- Road injury
PhD Study 1: Morbidity and Longevity after Stroke

Stroke study: brief description  
(PhD student Padma Chutoo)

• The study is designed to model the impact of ischaemic stroke and transient ischaemic attack (TIA) on longevity and morbidity risks. The data is based on the UK THIN database.

• The study period is from 2004 up to 2017.

• Selection of cases: patients who have had the ischaemic or transient ischaemic attack type of stroke for the first time after 2004.

• Exclusion criteria: prior major cancers, dementia, heart failure, chronic kidney disease stages 3+ and haemorrhagic stroke.

• 83,379 cases were matched to 236,687 controls by practice, age and sex.

• The primary outcome is all-cause mortality. The secondary outcomes are further strokes, dementia, heart failure, myocardial infarction, pulmonary arterial disease.

• Variables of interest:
  • Antihypertensives, Anticoagulants, Lipid regulating drugs, Asthma, Atrial Fibrillation, Chronic Kidney Disease, Coronary heart disease, PAD, Hypothyroidism, COPD, Diabetes, Hypercholesterolemia, Hypertension, Depression, and Socio-economic status.
PhD Study 2: Diabetes Mellitus Type 2

World diabetes cases expected to jump 55 percent by 2035

Current and projected cases of diabetes by region

<table>
<thead>
<tr>
<th>Region</th>
<th>2013</th>
<th>2035</th>
<th>Projected Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>South and Central America</td>
<td>59.8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Africa</td>
<td>109.6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North America/Caribbean</td>
<td>37.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle East/North Africa</td>
<td>96.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td>22.4%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast Asia</td>
<td>70.6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Pacific</td>
<td>46.0%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Top 10 countries by number of people with diabetes in 2013, ages 20 to 79

<table>
<thead>
<tr>
<th>Country</th>
<th>Cases (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>98.4</td>
</tr>
<tr>
<td>India</td>
<td>65.1</td>
</tr>
<tr>
<td>U.S.</td>
<td>24.4</td>
</tr>
<tr>
<td>Brazil</td>
<td>11.9</td>
</tr>
<tr>
<td>Russia</td>
<td>10.9</td>
</tr>
<tr>
<td>Mexico</td>
<td>8.7</td>
</tr>
<tr>
<td>Indonesia</td>
<td>8.5</td>
</tr>
<tr>
<td>Germany</td>
<td>7.6</td>
</tr>
<tr>
<td>Egypt</td>
<td>7.5</td>
</tr>
<tr>
<td>Japan</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Source: International Diabetes Federation
DM-II study: brief description
(PhD student Njabulo Ncube)

• The study is designed to model the impact of diabetes mellitus II (DM-II) on longevity and morbidity risks. The data is based on the UK THIN database.
• The study period is from 2004 up to 2017.
• Selection of cases: only DM-II cases diagnosed from 2004 and who had no other severe conditions diagnosed before DM-II diagnosis date were included.
• 138 979 cases were selected and matched to 299 429 controls by practice, age and sex (matching ratio 1:3).
• The primary outcome is all-cause mortality. The secondary outcomes are amputation, cognitive impairment, CKD 3-5, heart failure, myocardial infarction, pulmonary vascular disease, stroke, cancer and dementia.
PhD Study 3: Hormone Replacement Therapy

 Mean age < 60 years
 Hormone replacement and total mortality

<table>
<thead>
<tr>
<th>Study</th>
<th>Treatment</th>
<th>n/N</th>
<th>Control</th>
<th>n/N</th>
<th>Odds Ratio (95% CI Random)</th>
<th>Weight %</th>
<th>Odds Ratio (95% CI Random)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angerer 2000</td>
<td>1 / 215</td>
<td>0 / 106</td>
<td></td>
<td>1.9</td>
<td>1.49 [0.66, 3.38]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arendroth 2002</td>
<td>1 / 108</td>
<td>0 / 53</td>
<td></td>
<td>1.9</td>
<td>1.47 [0.86, 2.52]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Giske 2002</td>
<td>1 / 123</td>
<td>0 / 43</td>
<td></td>
<td>1.9</td>
<td>1.07 [0.64, 2.12]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guidozzi 1999</td>
<td>32 / 62</td>
<td>41 / 68</td>
<td></td>
<td>41.0</td>
<td>0.70 [0.35, 1.41]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hall 1994</td>
<td>3 / 37</td>
<td>3 / 16</td>
<td></td>
<td>6.7</td>
<td>0.38 [0.07, 2.14]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hall 1998</td>
<td>0 / 40</td>
<td>1 / 20</td>
<td></td>
<td>1.9</td>
<td>0.16 [0.01, 1.42]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Konmalchen 1999</td>
<td>1 / 115</td>
<td>2 / 115</td>
<td></td>
<td>3.4</td>
<td>0.50 [0.04, 5.54]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kyllonen 1998</td>
<td>1 / 52</td>
<td>0 / 26</td>
<td></td>
<td>1.9</td>
<td>1.54 [0.06, 39.21]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lindsay 1976</td>
<td>1 / 63</td>
<td>1 / 57</td>
<td></td>
<td>2.5</td>
<td>0.90 [0.06, 14.78]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MacDonald 1994</td>
<td>1 / 22</td>
<td>1 / 22</td>
<td></td>
<td>2.5</td>
<td>1.00 [0.06, 17.07]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mitro 1998</td>
<td>0 / 15</td>
<td>1 / 13</td>
<td></td>
<td>1.8</td>
<td>0.31 [0.01, 8.38]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moskilde 2000</td>
<td>4 / 502</td>
<td>9 / 504</td>
<td></td>
<td>14.2</td>
<td>0.44 [0.14, 1.44]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nachtsadl 1979</td>
<td>3 / 84</td>
<td>7 / 84</td>
<td></td>
<td>10.3</td>
<td>0.41 [0.10, 1.63]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pepa 1995</td>
<td>3 / 701</td>
<td>0 / 174</td>
<td></td>
<td>2.3</td>
<td>1.75 [0.09, 34.01]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perez-Jaraiz 1996</td>
<td>0 / 26</td>
<td>1 / 52</td>
<td></td>
<td>1.9</td>
<td>0.65 [0.03, 16.45]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rava 1999</td>
<td>0 / 110</td>
<td>1 / 109</td>
<td></td>
<td>1.9</td>
<td>0.33 [0.01, 8.12]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Watts 2000</td>
<td>1 / 303</td>
<td>0 / 103</td>
<td></td>
<td>1.9</td>
<td>1.03 [0.04, 25.39]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total (95% CI) 53 / 2576  68 / 1565

Test for heterogeneity p = 0.99
Test for overall effect p = 0.83

Source: J Gen Intern Med. © 2004 Blackwell Publishing

Salpeter et al., J Gen Intern Med. 2004;19(7)

North America hormone replacement therapy market share, by product, 2012-2022 (USD Million)

https://www.grandviewresearch.com/industry-analysis/hormone-replacement-therapy-market

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HRT study: brief description
(PhD student Nurunnahar Akter)

- The study is designed to model the impact of hormone replacement therapy (HRT) prescription on longevity and morbidity risks. The data is based on the UK THIN database.
- The study period is from 1984 up to 2017.
- Selection of cases: women aged 46 years and above who received any kind of oral and transdermal HRT.
- Exclusion criteria: prior cancers, acute myocardial infarction (AMI), serious heart failure, stroke (except TIA), chronic kidney disease (CKD) stage 3-5, dementia, oophorectomy before age 45, premature ovarian insufficiency, premature menopause and surgical menopause before age 46.
- 117,627 cases were matched to 251,461 controls by GP practice and age.
- The primary outcome is all-cause mortality. The secondary outcomes are osteoporosis, dementia, cardiovascular disease, cancer and diabetes.
Poll 3

Please type in a key word (or expression) that represents the most important takeaway from this webinar in your mind.
Summary

- Estimating longevity risk and evaluating associated uncertainty is one of the main topics of concern to actuarial community.

- Modelling mortality experience in individual level health data from large health databases can:
  - Establish and quantify the drivers of changes in longevity
  - Help predict how these drivers may change over time

- The results can be translated into individual and population level life expectancy changes.

- Models that allow for differences in prevalence/treatments within the population can be used to transpose results to apply to a sub-population (of insured lives, for example).
Summary

• Changes in the prevalence of the risk factor of interest are reflected in the life expectancy at the population level, illustrating:
  – how much the risk factor of interest has already contributed to changes in past longevity improvements and
  – how continuing trends of the prevalence of the risk factor of interest can affect future life expectancy.

• These calculations can be informative for mortality projections of populations of insureds and pension schemes.
Summary

Case studies presented here on:

• Statin prescription
• Intensive systolic blood pressure control

Outline of other target conditions and interventions for the project:

• Stroke
• Diabetes Mellitus Type 2
• Hormone Replacement Therapy
The views expressed in this presentation are those of the presenter.
References


• Spiegelhalter (2016) How old are you, really? Communicating chronic risk through ‘effective age’ of your body and organs. *BMC Medical Informatics and Decision Making*, 16:104


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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 ‘Use of Big Health and Actuarial Data for understanding Longevity and Morbidity Risks’ research programme is being funded by the ARC.

www.actuaries.org.uk/arc