Using epidemiological research to estimate impaired life expectancy

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What is Life Worth?
A Transatlantic Dialogue on Compensation
CAVOL June 2026

Who estimates life expectancy?

I'm delighted to be at this workshop, to learn from others.

Lawyers instruct experts to estimate life expectancy (LE).

- **Medical doctors** Courts in the UK often prefer medical doctors to be asked for life expectancy estimates.
- **Actuaries** National life tables, national statistics
  Rating of substandard lives. UK: Ogden tables
- **Demographers** National life tables
  – quality of vital statistics, choice of methods.
- **Epidemiologists and medical statisticians**
  - Data: routine, observational, experiment
  - Mainly comparison of mortality rates, some survival cohorts
  - Prognostic index: quite a large literature

Actuaries

In the UK, the main actors are:
Office for National Statistics (ONS),
Government Actuary's Department (GAD),
Institute and Faculty of Actuaries (IFoA),
Continuous Mortality Investigation of the IFoA,
Longevity Science Advisory Panel (LSAP)

ONS, CMI, LSAP consider mortality projections and future changes in mortality experience.

Central to almost all LE estimation methods, particularly

q_x "the probability of dying between exact age x and (x+1)".

Determines a life table.

Thank you to all ONS staff and others for q_x.

Actuaries

rate up: assume person is x years older than real age.

Rating of substandard lives used in insurance to decide on cost of life insurance. Assumptions

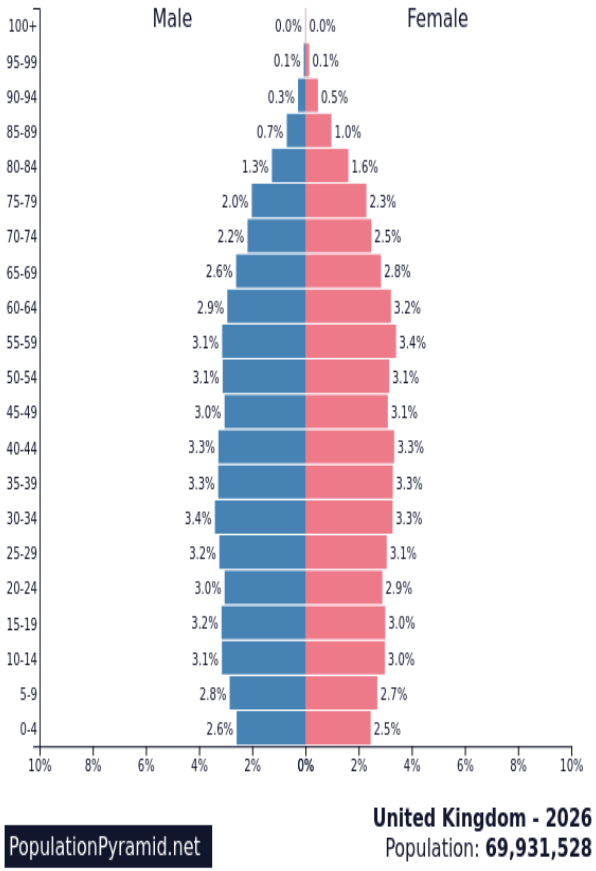
1. projected mortality rates for national population are correct
2. RR (mortality ratio) is correct; and
3. RR constant over future time.

Underestimates for older people: life insurance - "ratings overkill". RR assumed constant across ages, instead of converging to population mortality rates.

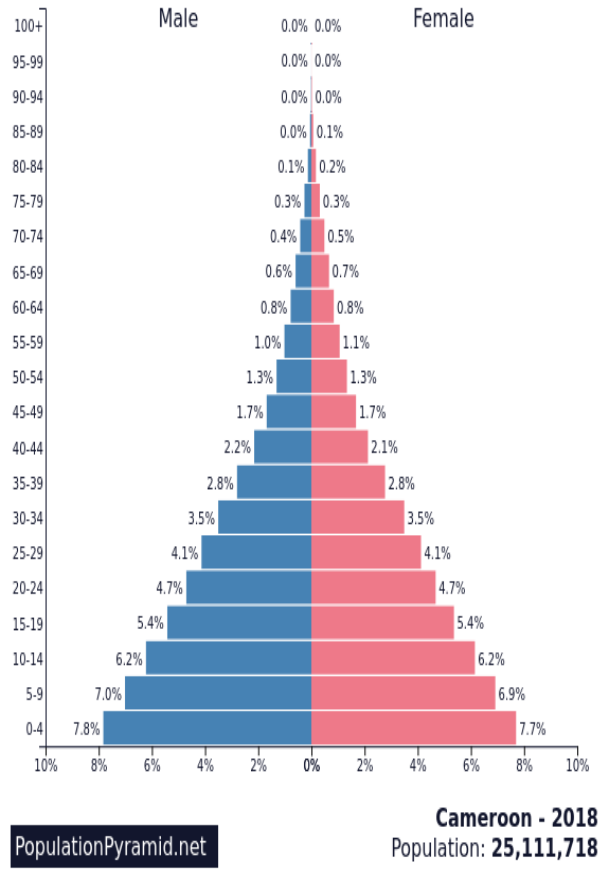
Ogden tables I'm looking forward to hearing the experts on this.

Demographers

Mr X was born in Cameroon to Nigerian parents; he came to live in the UK in 2003 at age 18. What do you think?



UK 2026 population pyramid



Cameroon population pyramid

Medical doctors: Physician

Calculations

Age at death:	54 years
Baseline mortality rate:	100%
Alcoholism:	+500%
Hyperlipidaemia:	+25%
Depression:	+100%
Cigarette smoker:	+75%
Total mortality rate:	800%
Life expectancy:	15.8 years
Age of mortality:	69.8 years
Ogden prediction:	33.07 years
Reduction in life expectancy:	17.27 years

Adds percentages?

Medical doctors: Paediatrician, Neurosurgeon

"None of my patients is over 18 years old, so I expect this child not to live beyond 18 years."

Life expectancy is reduced after traumatic brain injury. . . . Mr AB has both cognitive and physical disabilities. Using the ONS life expectancy calculator, the median life expectancy of a 67 year-old man (Mr AB's age at the time of the injury) is 85 years, with a 1 in 4 chance of surviving to 92. However, around 25% of the cohort die before the age of 80. While it is difficult to predict accurately, I would expect Mr AB to be in this lower quartile, and it is extremely likely that his life expectancy has been reduced as a result of the index event.

Mr AB was 69 years at the date of the report. Does this matter?

Statisticians

Academic statisticians also contribute to the ONS life tables: Hilton, Dodd, Forster, Smith 2019: generalized additive model (GAM) for mortality for majority of age range, parametric model for older ages.

Typical instructions I receive:

X was involved in a road traffic accident. He suffered a severe traumatic brain injury . . . beneficial to obtain a report from a statistical perspective considering our client's life expectancy.

Z suffers with Mosaic Down Syndrome. Assuming Z had not been assaulted, and he had received specialist inpatient treatment for PTSD, please comment on Z's life expectancy.

Y used coccaine and heroin, smoked 40 cigarettes per day . . .

W drank a large glass of wine daily.

Statisticians . . . well, this one

Initially, life expectancy for people with cerebral palsy, jointly with paediatric epidemiologist, Peter Pharoah.

- Used my own and other research.
- Customised life table from geographical cohort
  - for age, motor, mental, visual impairments.
- How to extrapolate beyond oldest known age?
  $q_x + A$, where A death rate from customised life table

Only two "expert opinions' worldwide. (Oh, dear. Not good)
Californian Life Expectancy Project (LEP): register of people receiving state services.
We regularly disagree, methods changed, other neurological injuries

Statisticians . . . my approach

Adjust for obesity, smoking, alcohol, fitness, drug misuse . . .

- Review recent research literature on neurological injuries.
- Generally motor, mental, sensory impairments important.
- Review recent research, systematic reviews.
- Decide on factors to include in adjustments.
- Try to explore dependence, e.g. obesity, diabetes, smoking
- Double counting if include obesity, diabetes, high cholesterol, so provide multiple estimates.
- Published mortality statistics: RR, SMR, OR, HR, or Relative survival
- Most annoying statistic is average years of life lost.

Now also cancer, amputation, . . .

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Mortality risk estimators, RR, OR, HR, SMR, EDR

Period q_x age 65 in 2026:
women 757.79 100000, men 1181.84/100000

Relative risk (RR): death rate men/ death rate women:
$1.559588 = (1181.84/757.79) \approx 1.56$.
Physician expressed RR 1.56 as +56%

Hazard ratio (HR) similar to RR (discuss?)

Odds ratio (OR): odds of death men/ odds death women
$1.552924 = (1.18 \times 98.9)/(0.76 \times 99.2) \approx 1.55$.

Excess death rate (EDR): death rate men - women:
$424.05/100000 = 1181.84/100000 - 757.79/100000 \approx 0.42\%$.

Relative survival: % of general population life expectancy.

Standardised mortality Rate (SMR):
adjusted for age and sex distribution to a standard population

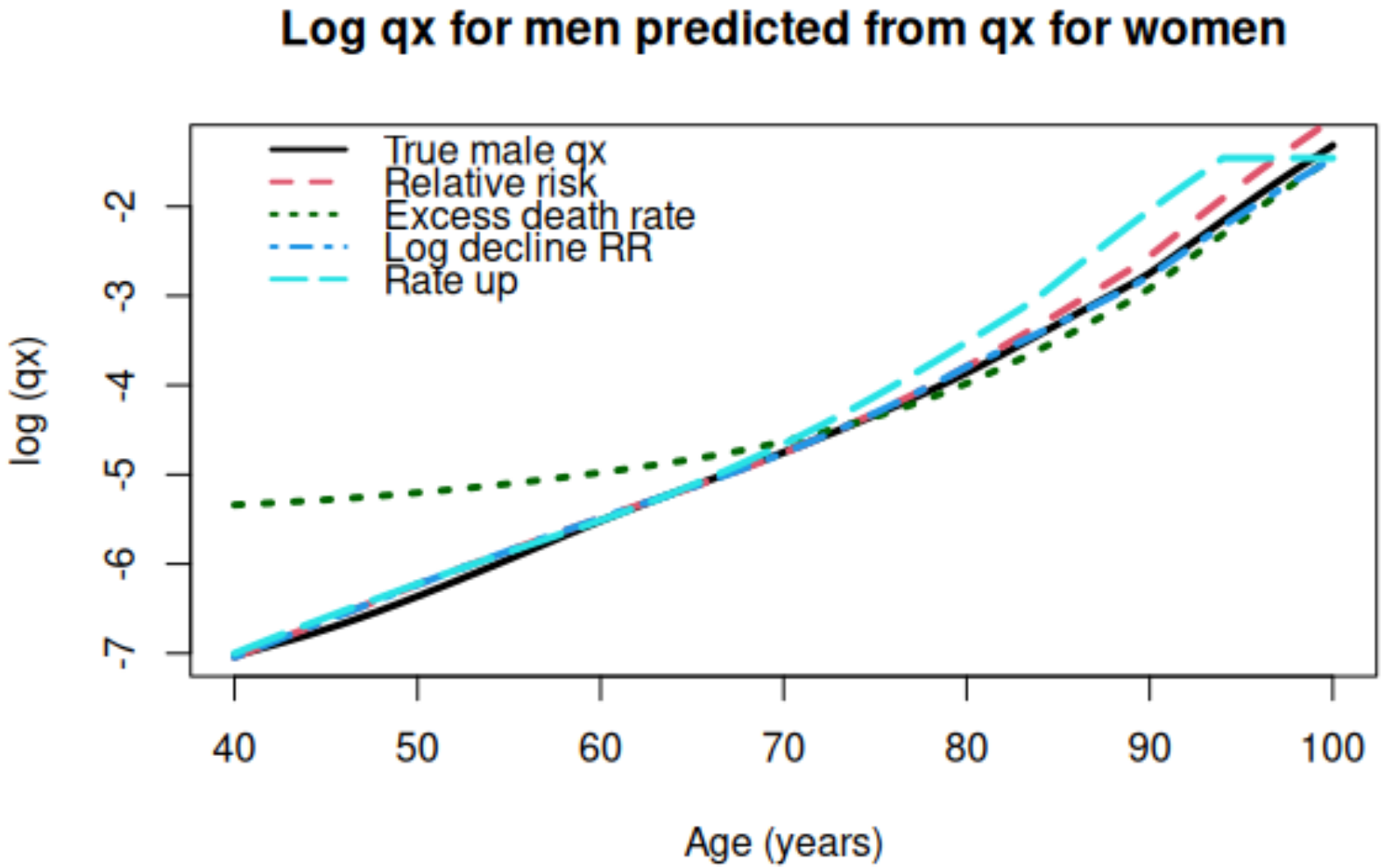
Statisticians . . .

Choices for modifying q_x to $q_{x,i}$ for individual i

- Rate up: $q_x = q_{x+k}$, choose k.
- Add excess death rate $\implies$ RR converges to 1 with age.
- Add excess death rate, but constrain RR to minimum RR > 1.
- Multiply q_x, constant RR $\implies$ increasing excess death rate.
- Multiply q_x, constant RR, log-linear decrease in RR to 0: from 80 (?) to 100 (?) years.
- Modify to have constant proportional life expectancy: $e_{x,i}/e_x = k \implies q_{x,i} = q_x + (1-k)e_x/k$

Strauss, Vachon, Shavelle 2005.

Modified mortality rates



Modified mortality rates

Life expectancy at age 65 years for men

- Rate up by 6 years: 22.9 years
- Add excess death rate: 26.05
- Multiply constant RR: 24.9 years
- Constant RR, log-linear decrease in RR to 80 to 100: 25.6

25.6 years.

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What criteria to evaluate methods?

In biostatistics, common measures for patient groups are:

Calibration: predicted 1, 2, ...10th decile risk = observed %.
Fitted model against Kaplan-Meier estimates.

Discrimination: correct ordering of time to event for random pair

Overall performance: explained variation R^2 estimated in various ways, Brier score, mean squared error of prediction.

Reporting guidelines for research on predictions for individuals.

TRIPOD: **T**ransparent **R**eporting of a multivariable prediction model for **I**ndividual **P**rognosis **O**r **D**iagnosis

Short term (30 day mortality) or long term (10 year risk)
Often Cox regression on clinical dataset.

Conclusions

What criteria should we use to evaluate methods to estimate non-standard lives?

I'd like to use Kullbach-Leibler distance to compare methods – but what is the relevant comparison data? –
and can I access it?

Thank you