Centenarian survival: Stagnating or improving?

Jesús-Adrián Álvarez James W. Vaupel

alvarez@sdu.dk

Interdisciplinary Centre on Population Dynamics
University of Southern Denmark

Syddansk Universitet


100
Celebrate

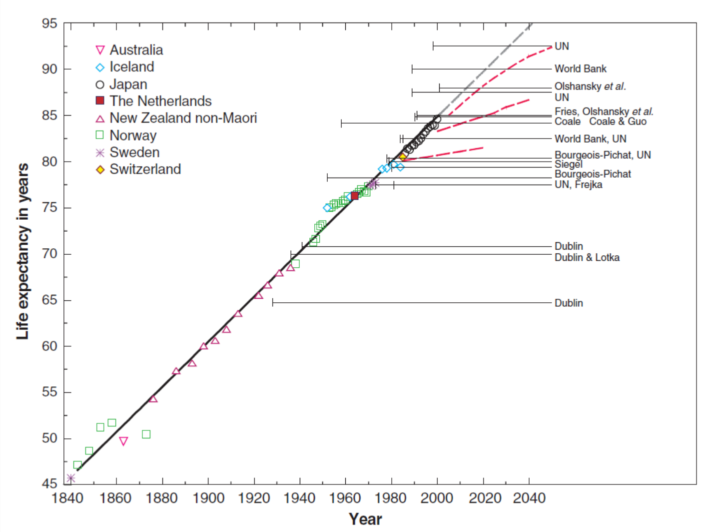

HAPPY
BIRTHDAY


100


100

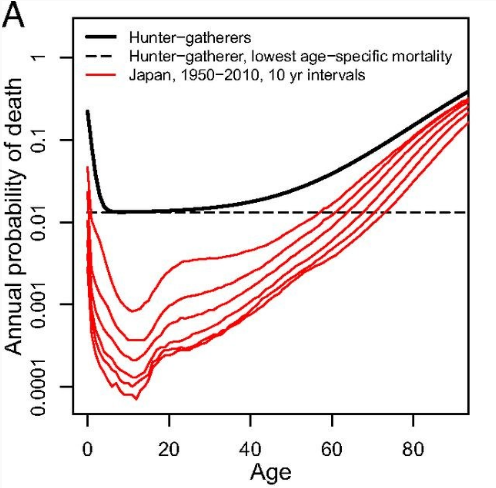
What do we know?

Broken limits to life expectancy



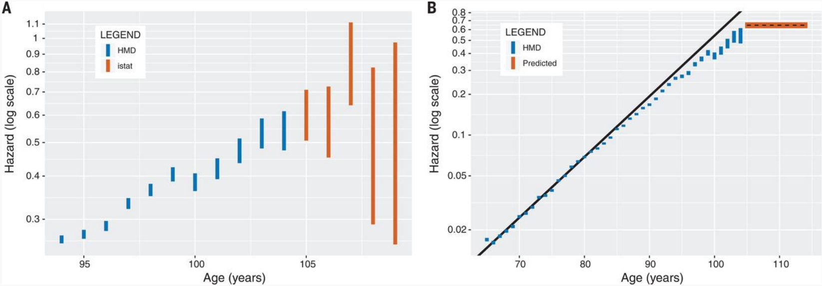
Oeppen and Vaupel. (2002), *Science.*

Mortality improvements in evolutionary context



Burger et al. (2014), *PNAS.*

The plateau of human mortality in Italy



Barbi et. al (2018), *Science.*

What about centenarians?

- Null mortality improvements after age 100 in **Sweden** and **Denmark** (Modig et al, 2017; Drefhal, 2016),

What about centenarians?

- Null mortality improvements after age 100 in **Sweden** and **Denmark** (Modig et al, 2017; Drefhal, 2016)**,**
- Medford et. al (2019) show that ***the oldest old (90th percentile) in Denmark have been getting older while there has been no evidence of any increase in lifespan for Swedes***.

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What do we want to know?

- Are centenarians **living longer**?
- Are there **mortality improvements** after age 100?
- How does the outstanding survival of **individuals** compare with the observed trends at the **population level**?

individuals

$\neq$

POPULATION

Unobserved Heterogeneity

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At a population level this creates **heterogeneity**.

Data and methods

Data

France, England and Wales, Italy and Japan.

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Raw data from the Human Mortality Database,

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10-year birth cohorts of females born between 1850-1904,

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Raw data from the Human Mortality Database,

10-year birth cohorts of females born between 1850-1904,

starting at age 80.

- Life expectancy at age 100, $\bar{e}(100)$

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- Lifespan variability,

$$\bar{e}^{\dagger}_{100} = \frac{\int_{100}^{\omega} d(x,y)\bar{e}(x,y)dx}{l(100,y)},$$

$$\bar{H} = \frac{\bar{e}^{\dagger}_{100}}{\bar{e}(100)},$$

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- Rates of mortality improvement:

$$\bar{\rho}(x,y) = -\frac{\frac{\partial \bar{\mu}(x,y)}{\partial y}}{\bar{\mu}(x,y)}.$$

Z: random latent variable, *frailty*.
$\bar{\mu}(x,t)$: hazard for the entire population,
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$\bar{\mu}(x,t)$: hazard for the entire population,
$\mu(x,t)$: hazard for individuals,
$\bar{\mu}(x,t)$ follows a **Gamma-Gompertz** (ΓG) distribution:

$$\bar{\mu}(x,t) = \frac{\alpha e^{x}}{1 + (\frac{\alpha\gamma}{\beta})(e^{\beta x} - 1)}. \tag{1}$$

In a ΓG setting at age 80:

$$\bar{\mu}(80, t) = \mu(80, t)\bar{z}(80),$$

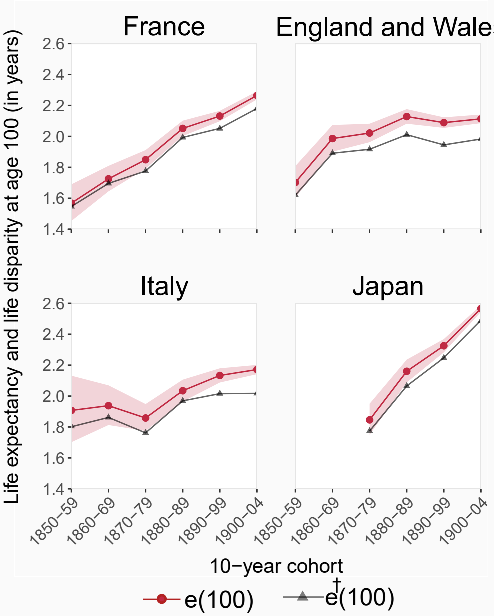
Therefore,

$$\frac{\bar{\rho}(x - 80, t)}{\bar{\rho}(80, t)} = \frac{\rho(x - 80, t)\bar{s_c}(x - 80, t)^{\gamma}}{\rho(80, t)}.$$

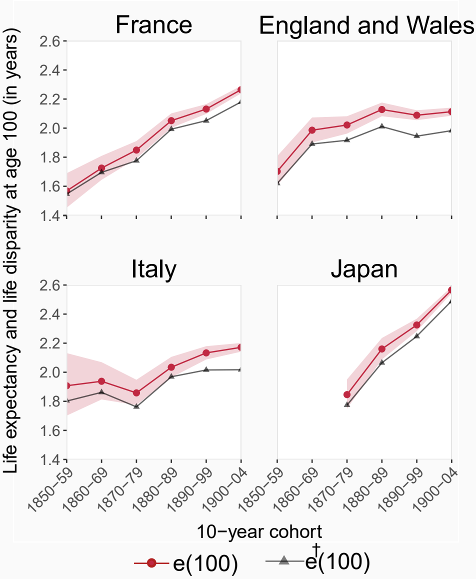
Vaupel and Missov. (2014), *Demographic Research.*

The whole population

Life expectancy and life disparity at age 100

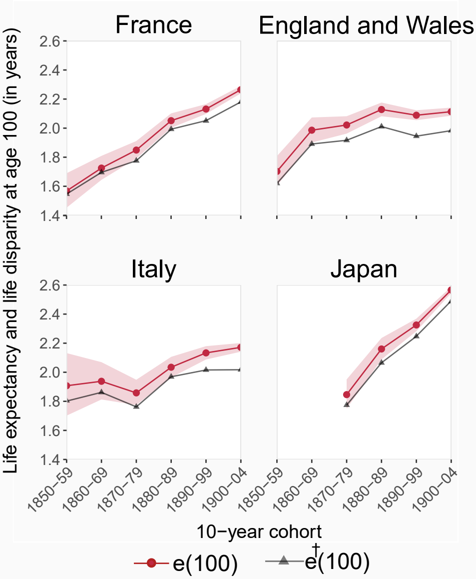


Life expectancy and life disparity at age 100



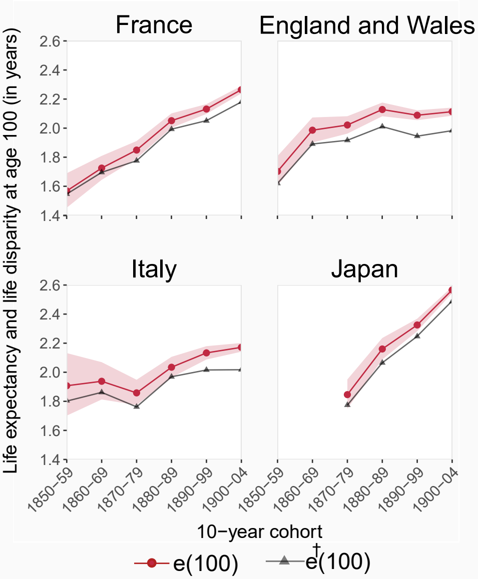
1. Lifespans are highly variable,

Life expectancy and life disparity at age 100



1. Lifespans are highly variable,
2. No compression towards a wall of death,

Life expectancy and life disparity at age 100



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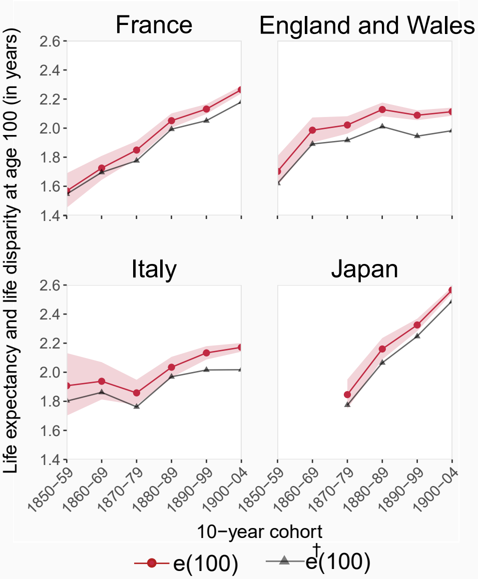
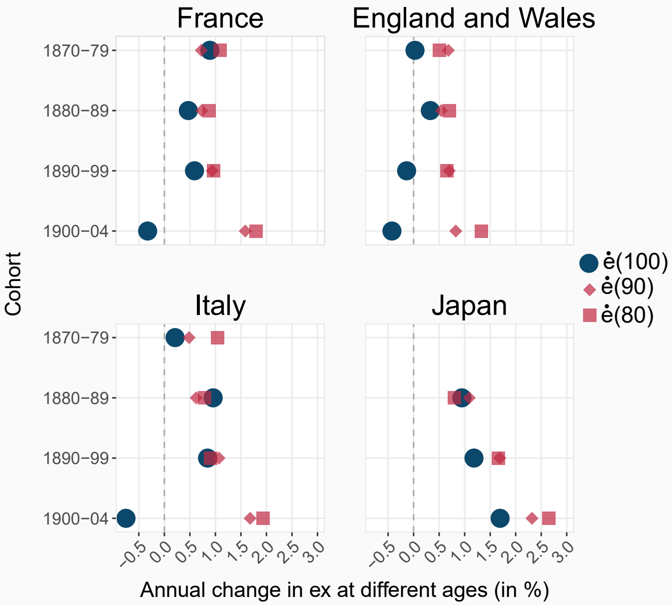


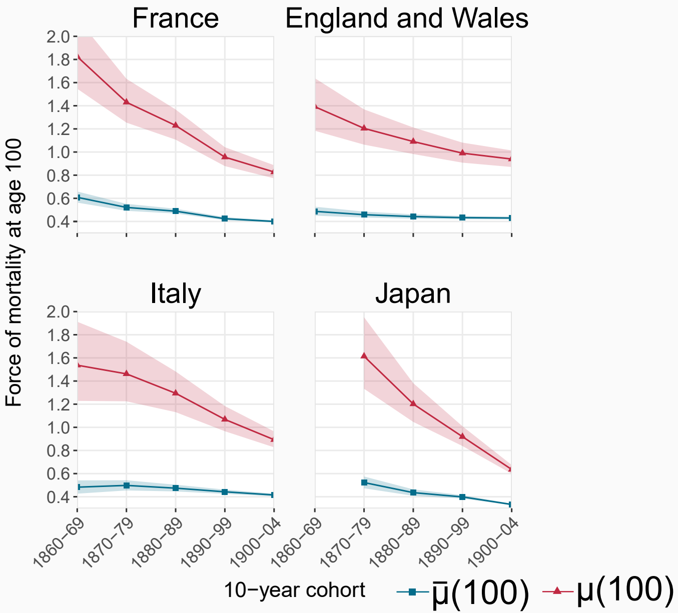
1. Lifespans are highly variable,
2. No compression towards a wall of death,
3. Keyfitz's entropy close to unity: changes in death rates = changes in e_{100},
4. Half of centenarians die before e_{100} and half of them survive to older ages.

Rate of change of $\bar{e}_{100}$

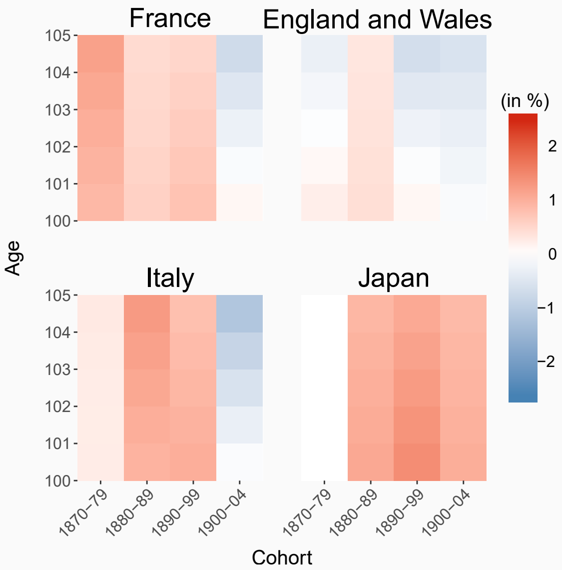


Individuals vs the whole population

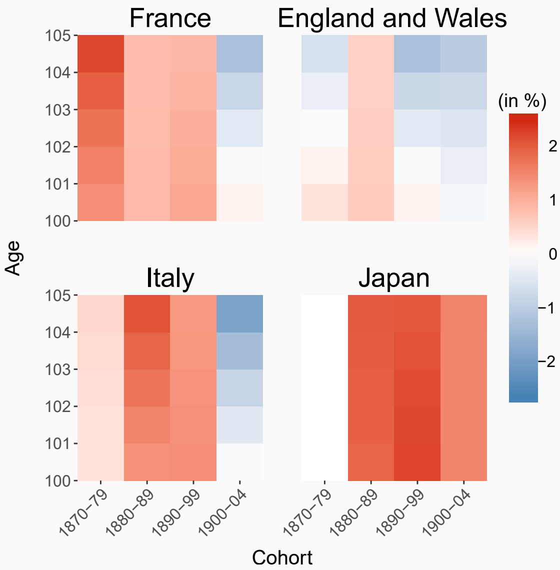
Mortality hazard at age 100



Mortality improvements for the total population



Mortality improvements for individuals



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- Mortality is **improving**,
- Lifespans above age 100 are highly **heterogeneous**,
- **Heterogeneity** prevents populations from further mortality improvements.

Why?

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