How many times have our lives been saved? A reappraisal of the resuscitation approach using HMD data

Vanessa di Lego

Vienna Institute of Demography

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Vanessa.DiLego@oeaw.ac.at

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Motivation: Vaupel and Yashin (1986, 1987)

Mortality improvement

1. Reduce force of mortality:

$$\mu_{(x)}$$

2. Increase force of lifesaving:

$$\lambda_{(x)}$$

New mortality regime:

1. New mortality regime:

$$\mu*_{(x)} = \mu_{(x)} - \lambda_{(x)}$$

2. Rate of progress:

$$\rho = -d\mu_{(x)}/dt)/\mu_{(x)}$$

Rationale

Let $\mu(x)$ be the force of mortality at age x and $l(x)$ survivorship (radix=1), we know that:

$$l(x) = \exp\left[-\int_0^x \mu(t)dt\right] \tag{1}$$

And that life expectancy is:

$$e(x) = \int_x^\omega l(t)dt/l(x) \tag{2}$$

Suppose in addition that $\mu* \leqslant \mu(x)$, so that two regimes are considered.

Rationale

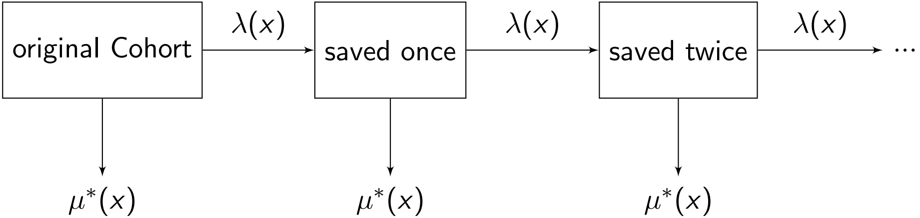


Figure 1: Life saving process: i resuscitations

And now let $l_i(x)$ be the probability that an individual will be alive and in state i at age x. $i=$ the number of times an individuals life has been saved.

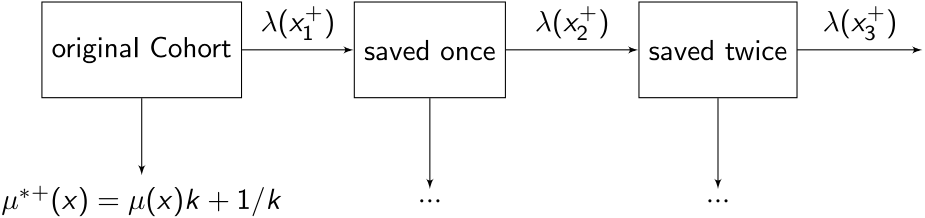


Figure 2: Life saving process: i resuscitations

And now let $l_i(x)$ be the probability that an individual will be alive and in state i at age x. $i=$ the number of times an individuals life has been saved.

A demographic model of lifesaving

This takes us to the "revivorship function"

$$l^*(x) = l(x) + l_1(x) + l_2(x) + ... \tag{3}$$

And that the chances of repeated resuscitation are:

$$l_i(x) = l(x)\Lambda x^i / i!, i = 0, 1, 2, ... \tag{4}$$

Where:

$$\Lambda(x) = \int_0^x \lambda(t)dt \tag{5}$$

And it follows from 1 and 15 that:

$$\color{red}{\Lambda(x)} = \ln(l^*(x)/l(x)) \tag{6}$$

Decomposing survival and life expectancy

The relationship between survival under the new and old regimes can be established through:

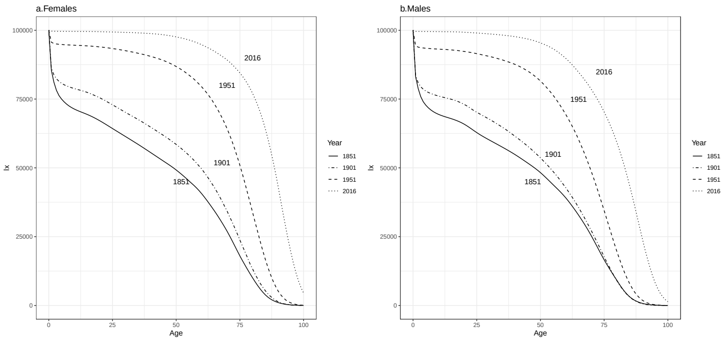
$$l^*(x) = l(x) + l(x)\,\Lambda(x) + [l(x)\Lambda(x)^2]/2 + \ldots + [l(x)\Lambda(x)^i]/i! \quad (7)$$

And also decompose the value of life expectancy into:

$$\tau_i = \int_0^\omega l_i(x)dx = \int_0^\omega l(x)\Lambda(x)^i dx/i!. \quad (8)$$

Preliminary results: France

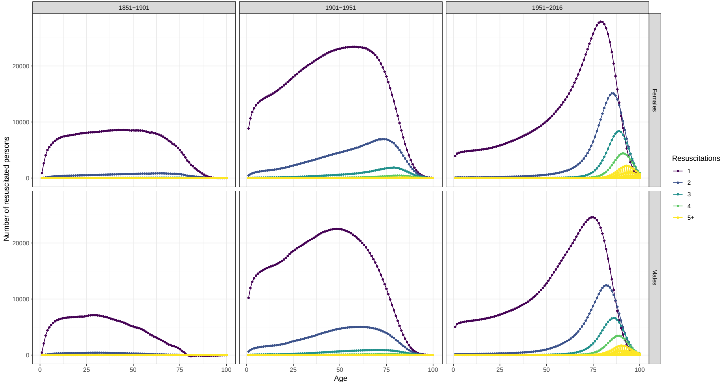
Figure 3: Life table survival (l_x), by sex, 1851-2016, France



Source: HMD

Preliminary results: France

Figure 4: Number of times the resuscitated had their deaths averted, by sex, 1851-2016, France



Source: HMD

Preliminary results: France

Table 1: Mortality improvement and number of resuscitated i, females, 1951-2016

	Survivor			Number of Resuscitation				
Age	l	l^*	$l^* - l$	l_1	l_2	l_3	l_4	l_5+
10	94573	99586	5013	4885	126	2	0	0
30	92596	99232	6636	6409	222	5	0	0
50	86836	97598	10762	10146	593	23	1	0
70	64186	89181	24995	21110	3471	381	31	2
80	33775	77040	43265	27851	11483	3156	651	124

Source: HMD

Preliminary results: France

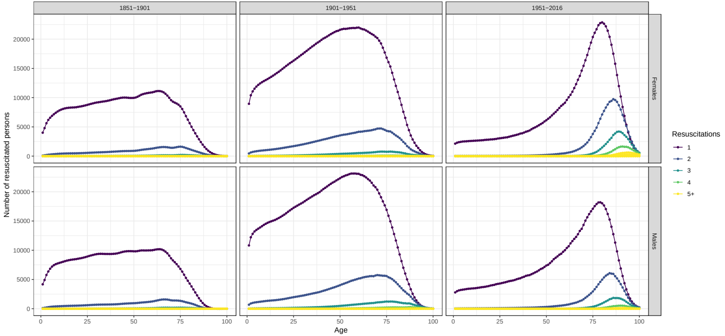
Table 2: Mortality improvement and life years lived in each resuscitation state i, females

	Life expectancy			Decomposing improvement			
Regime	ex^*_0	ex_0	$ex^*_0 - ex_0$	τ_1	τ_2	τ_3	**%diff**
1851-1901	48.86	42.41	6.45	5.93	0.48	0.02	91.99
1901-1951	68.90	48.86	20.04	15.91	3.36	0.61	79.40
1951-2016	85.32	68.90	16.42	11.10	2.98	1.24	67.64

Source: HMD

Preliminary results: Denmark

Figure 5: Number of times the resuscitated had their deaths averted, by sex, 1851-2016, Denmark



Source: HMD

Preliminary results: Denmark

Table 3: Mortality improvement and life years lived in each resuscitation state i, females

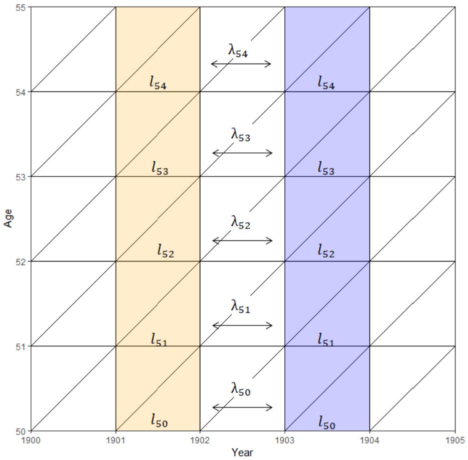
	Life expectancy			Decomposing improvement			
Regime	ex^*_0	ex_0	$ex^*_0 - ex_0$	τ_1	τ_2	τ_3	**%diff**
1851-1901	54.56	46.22	8.34	7.50	0.76	0.06	89.98
1901-1951	72.15	54.56	17.59	14.81	2.41	0.30	84.21
1951-2016	82.79	72.15	10.64	7.38	1.81	0.61	73.61

Source: HMD

Discussion

- Averting deaths for the first time plays a major role in progress, but in the past five decades progress seems to be more spread out and the contribution of saving lives more times increases.
- Implications for how mortality improvement translates into life expectancy increase (lifetable,delayed death model or heterogeneity, stretched lifetimes?)
- How does the lifetable save lives? - how much does the heterogeneity counts?
- Decomposing entropy
- Cohort life table
- assessing limit ages

Figure 6: Resuscitation on the Lexis



Proportion of resuscitated $l_i(x)/l^*_{(x)} = exp[-\Lambda(x)][\Lambda(x)^i/i!]$

Age	Survivor			Number of Resuscitation				
	l	l^*	$l^* - l$	l_1	l_2	l_3	l_4	l_5+
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Thank you!

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Levels and Trends of Health Expectancy: Understanding its Measurement and Estimation Sensitivity