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

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Abstract

Vaupel and Yashin 1987b and Vaupel and Yashin 1987a developed a demographic model of lifesaving on which the concept of force of mortality μ_x is coupled with the notion of lifesaving $_x$. Their construct allows for assessing the formal relationships between survivorship, density distribution of deaths and life expectancy between two different regimes. In a context of mortality improvement, the new force of mortality can be seen as a decomposition of the old mortality regime μ_x plus a force of lifesaving $_x$ that prevents new deaths. At each age, a proportion δ of individuals who would have died are now resuscitated and given another chance. The process can be mathematically described by a factorial reminiscent of the Poisson distribution, resulting in a revivorship function that estimates the probability that an individual will be given a second chance (will be resuscitated) i times by age x. we use this relationship to assess how have gender gaps evolved throughout history estimate: 1. how many times deaths were averted among females relative to males; 2. the extra number of life years lived in each resuscitation

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state by females relative to males; and 3. and decompose life expectancy differentials into gains in τ_i life years at each averted death state. We argue that this approach can provide valuable insights into what is behind the total difference in life expectancy between males and females and also of mortality differentials throughout mortality transition.

Keywords: Resuscitation, Life Expectancy, Second-chance models, Mortality improvement

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1. Rationale

The demographic model of lifesaving on which the concept of force of mortality μ_x is coupled with the notion of lifesaving λ_x. This means that mortality improvement can be conceived as both a reduction on the force of mortality μ_x as a increase in the force of lifesaving λ_x. Hence, the link between the old and new mortality regimes can be established as:

$$\mu_x^* = \mu_x - \lambda_x \tag{1}$$

Where μ_x^* is the new mortality regime and μ_x the old one.

2. Data and Methods

This lifesaving force can lead to many lives being saved once, more than once or none at all, depending on the mortality progress and on the remaining life expectancy of the resuscitated and the relationship between survivorship in the new and old regimes are linked through. Survivorship in many states of revivorship can be defined as:

$$l_x^* = l_x + l_i x + l_2 x + ... \tag{2}$$

And that the chances of repeated resuscitation are:

$$l_i x = l_x \Lambda x^i / i!, i = 0, 1, 2, ... \tag{3}$$

Where

$$\Lambda(x) = \int_0^x \lambda(t)dt \tag{4}$$

Shown that

$$\Lambda(x) = \ln(l^*(x)/l(x)) \tag{5}$$

Further, it is possible to establish the relationship between survival under the new and old regimes can be established through:

$$l^*_{(x)} = l_{(x)} + l_x\Lambda_{(x)} + [l_{(x)}\Lambda^2_{(x)}]/2 + ... + [l_{(x)}\Lambda^i_{(x)}]/i! \tag{6}$$

From which we can decompose the value of life expectancy

$$\tau_i = \int_0^\omega l_i(x)dx = \int_0^\omega l_{(x)}\Lambda^i_{(x)}dx/i!. \tag{7}$$

Shown that

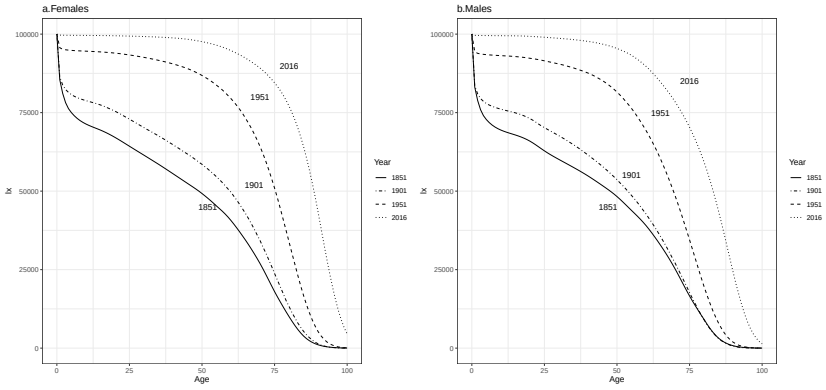
$$\Lambda(x) = \ln(l^*(x)/l(x)) \tag{8}$$

Using this relationship and HMD data from 1851-2016 for selected countries, we show how the mortality transition unfolded in terms of averting deaths and increasing the number of years of life lived in each resuscitation state.

3. Preliminary results

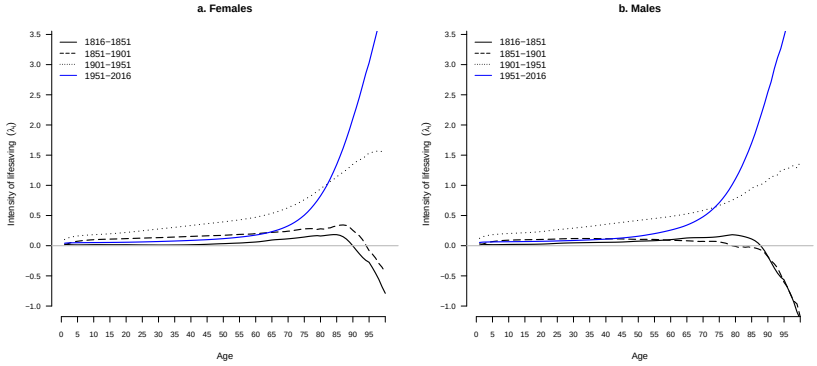
The l_x function for all countries show the well-known greatest improvement in mortality in history from the 1901 on.

Figure 1: Life table survival (l_x), by sex, 1851-2016, France



Interestingly, the intensity of lifesaving concentrates towards older ages as we reach recent years for all countries considered, reasuring how progress is now more intensively directed at people aged 75+.

Figure 2: Intensity of lifesaving force, by sex, 1851-2016, France



The number of times the resuscitated have their deaths averted gradually changes from the first death being more important to 5 times or more. This means that the structure of lifesaving is changing, and if in great part of the mortality transition saving once or twice represent almost the totality of mortality progress, now deaths that are more frequently postponed is rising.

Figure 3: Number of times the resuscitated had their deaths averted, by sex, 1851-2016, France

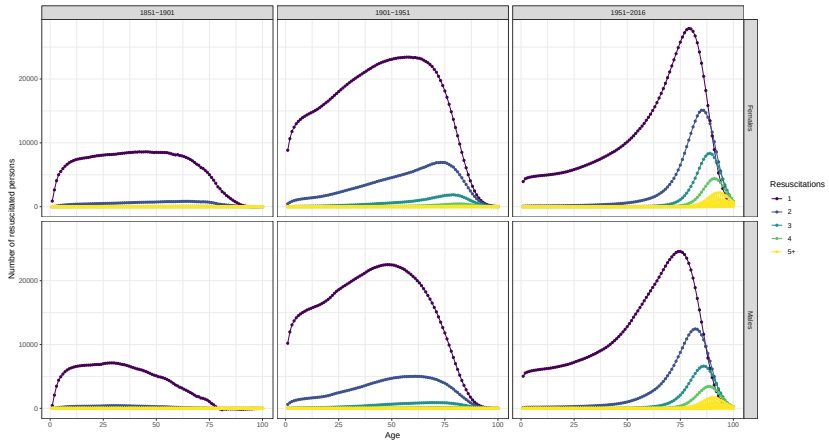
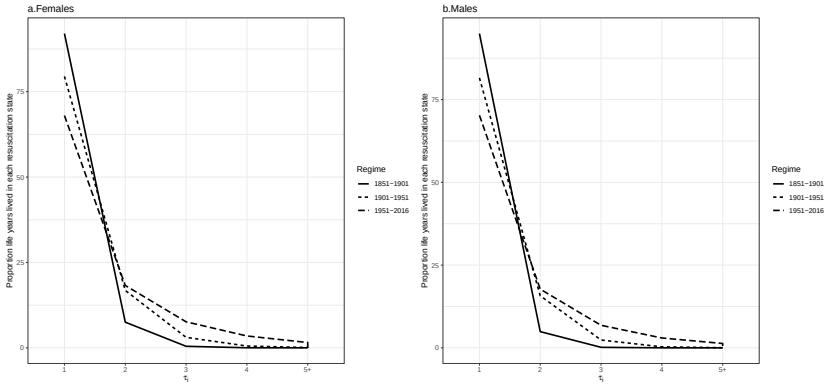


Figure 4: Proportion of total life expectancy lived by the resuscitated at each state, by sex, 1851-2016, France



In the case of France, as shown by the Figure above, the proportion of total life expectancy lived by the resuscitated at each state indicates the increase in the relative importance of being saved more than once. All other countries also face the same process.

Table 1: 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	2.98	1.81	1.24	67.64

Figure 5: Intensity of lifesaving force, by sex, 1851-2016, Sweden

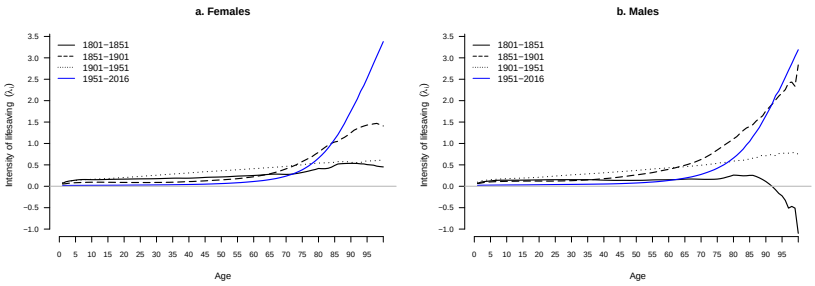


Figure 6: Number of times the resuscitated had their deaths averted, by sex, 1851-2016, Sweden

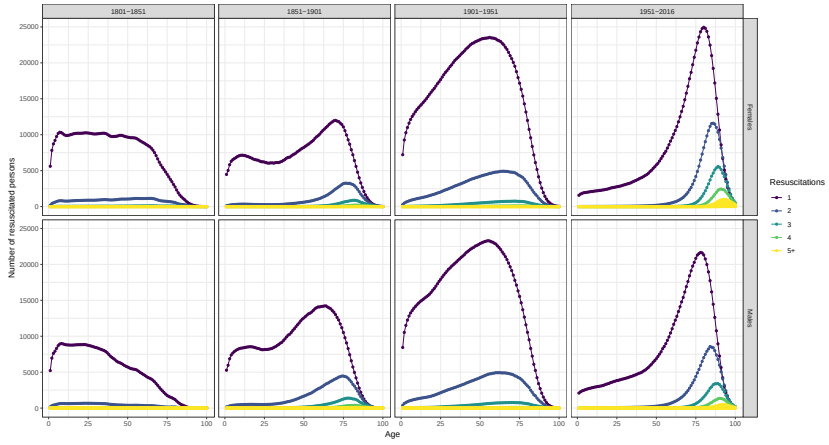


Figure 7: Proportion of total life expectancy lived by the resuscitated at each state, by sex, 1851-2016, Sweden

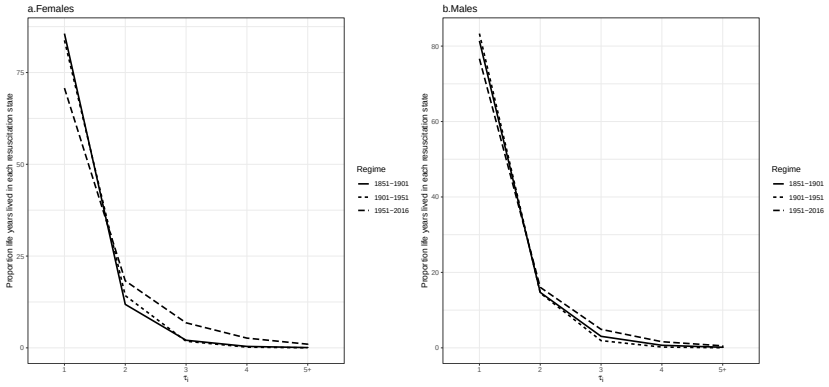


Table 2: Mortality improvement and life years lived in each resuscitation state i, males

	Life expectancy			Decomposing improvement			
Regime	${ex^*}_0$	ex_0	${ex^*}_0 - ex_0$	τ_1	τ_2	τ_3	**%diff**
1851-1901	51.65	41.21	10.44	8.48	1.53	0.31	81.30
1901-1951	70.04	51.65	18.39	15.30	2.67	0.35	83.24
1951-2016	80.57	70.04	10.53	8.05	1.68	0.17	76.50

Figure 8: Life table survival (l_x), by sex, 1851-2016, Denmark

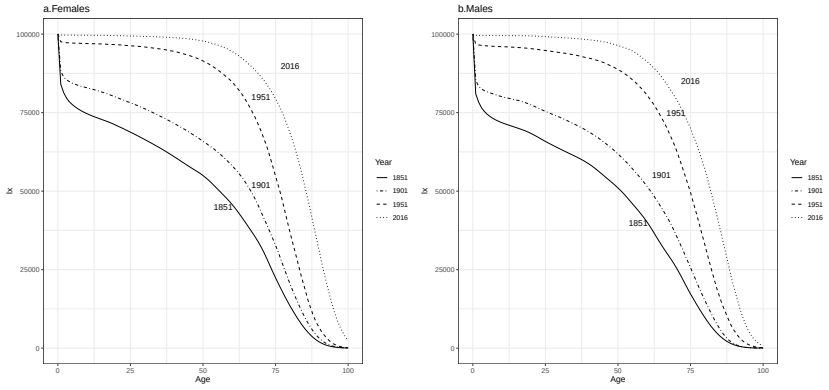


Figure 9: Intensity of lifesaving force, by sex, 1851-2016, Denmark

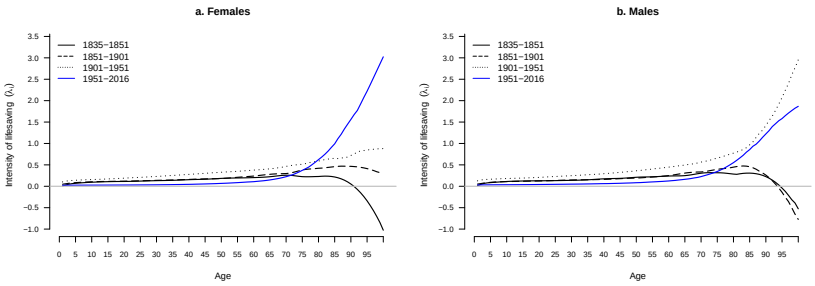


Figure 10: Number of times the resuscitated had their deaths averted, by sex, 1851-2016, Denmark

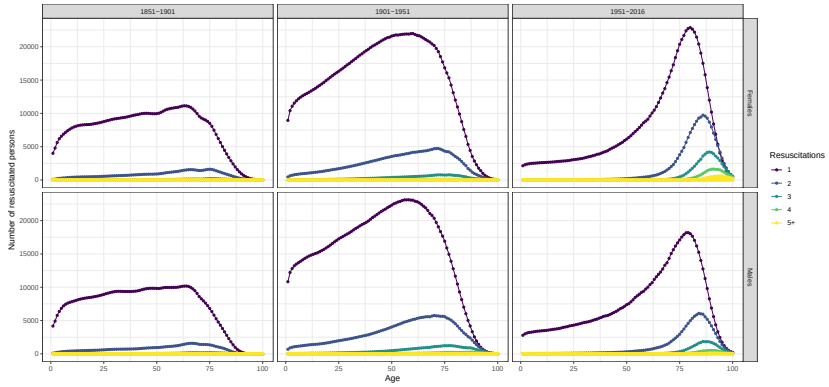


Figure 11: Proportion of total life expectancy lived by the resuscitated at each state, by sex, 1851-2016, Denmark

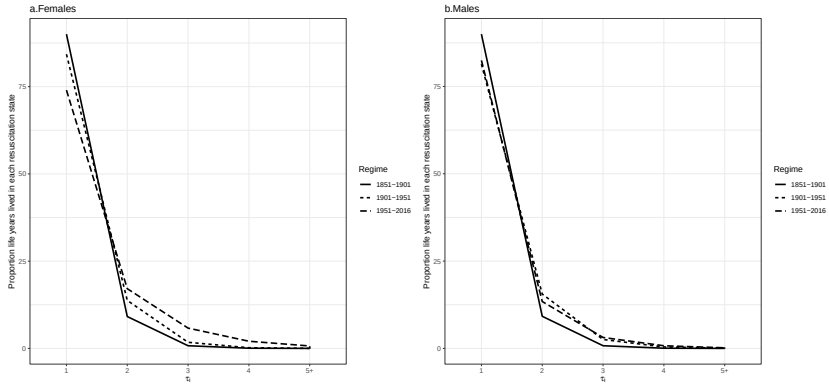


Table 3: Mortality improvement and life years lived in each resuscitation state i, females

	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

These preliminary results indicate that the resuscitation approach can yield interesting insights for our understanding of the changing structure in mortality improvement and how the years of life gained are spread out through the life course.

References

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[VY87b] James W. Vaupel **and** Anatoli I. Yashin. Targeting lifesaving: Demographic linkages between population structure and life expectancy. **in**: *European Journal of Population* 2.3-4 (), **pages** 335–360. ISSN: 0168-6577. DOI: https://doi.org/10.1007/BF0179659610.1007/BF01796596 10.1007/BF01796596. URL: `http://link.springer.com/10.1007/BF01796596`.