Life is short

But unlimited?

Göran Broström, CEDAR, Umeå University
: goran.brostrom@umu.se
: github.com/goranbrostrom
Web : capa.ddb.umu.se

Extremes, December 2017


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Human life is unlimited – but short

Holger Rootzén[1] · Dmitrii Zholud[1]

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Published online: 8 December 2017

Received from: Zentralblatt für Mathematik.

My review

Rootzén, Holger; Zholud, Dmitrii

Human life is unlimited – but short. (English) Zbl 1387.62120

Extremes 20, No. 4, 713-728 (2017).

The question whether the human lifespan has a finite limit or not is an old controversy, and the authors' contribution to the subject is that they provide a precise definition of the concept of a finite limit. They argue that there are three possibilities founded in extreme value theory: (i) The force of mortality tends to infinity at a finite age, and survival beyond that age is impossible, (ii) the force of mortality is constant after a certain age, e.g., 110 years of age, and life is unlimited but short, and (iii) the force of mortality is decreasing with age (after age 110), and life is unlimited. Furthermore, the authors claim that (ii) is the correct conclusion, given information available today, and they argue that recent contributions in the field that argues for alternative (i) do so based on inappropriate use of statistics, especially inadequate treatment of size-biased sampling. They come to their conclusions by handling the size-biased sampling correctly and by using the Generalized Pareto (GP) distribution as a model for supercentenarian life: Now available data points to the result that the special case of a GP distribution, the exponential (ii), with mean 1.34 years, is the distribution that fits data best. Furthermore, there is no sign of variation in this result with respect to sex, genetic background, lifestyle, etc. However, ten times more women than men reach the age of 110.

Reviewer: Göran Broström (Umea)

MSC:

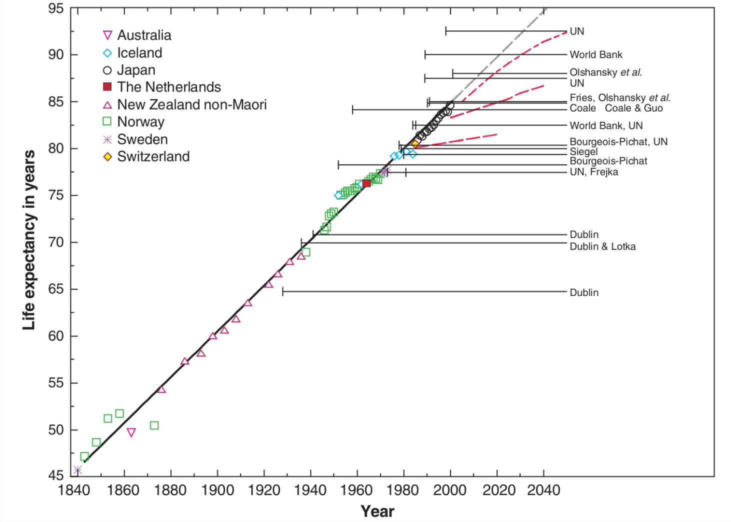
62P10	Applications of statistics to biology and medical sciences
62N01	Censored data models
60G70	Extreme value theory; extremal processes (probability theory)
62G32	Statistics of extreme values; tail inference

Keywords:
extreme human life lengths; no influence of lifestyle on survival at extreme age; no influence of genetic background on survival at extreme age; future record ages; supercentenarians; Jeanne Calment; limit for human life span; force of mortality; size-biased sampling; IDL; generalized Pareto distribution

What it is about

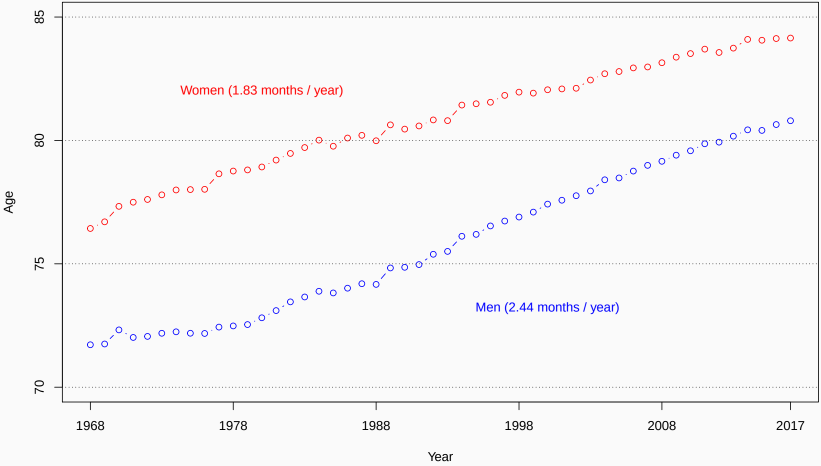
- Is human life unlimited?
- Are there any differences in survival at extreme age between
  - women and men,
  - different socioeconomic groups,
  - etc?

Broken Limits to Life Expectancy: Science 2002

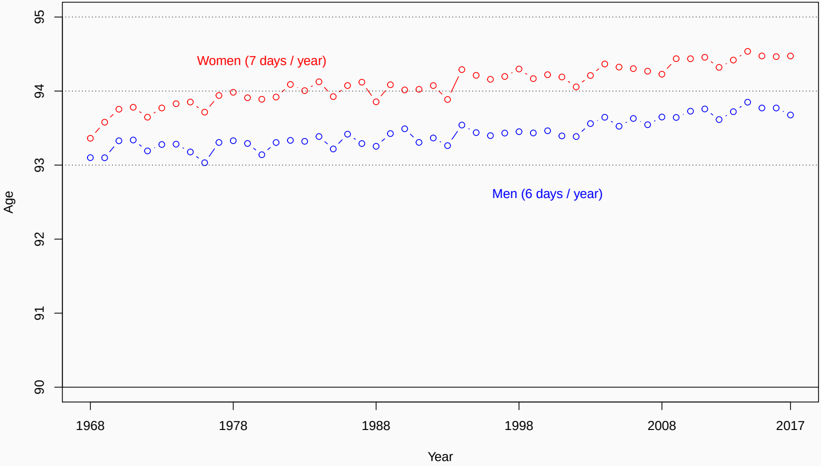


Authors: James Vaupel and Jim Oeppen. Gain / year: 3 months.

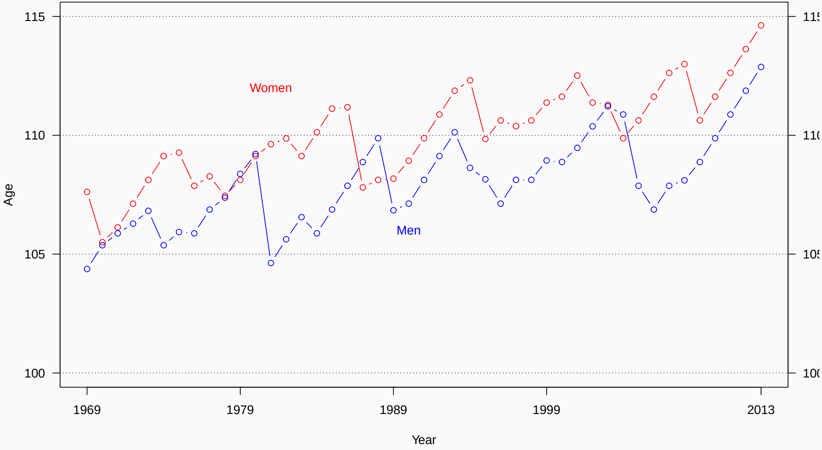
Sweden 1968-2014: Remaining life at birth



Sweden 1968-2014: Remaining life at age 90



Sweden 1969-2013: Maximum life



Chiyo Miyako, Japan

World's oldest person since 21 April, 2018. Age: 117.

(Age on picture: 114.)

Aftonbladet, 27 juli 2018

Världens äldsta person har dött – blev 117 år

▸ Japanskan Chiyo Miyako har avlidit ✓ ”Pratglad och vänlig person”

Now oldest: Kane Tanaka, Japan (115 years and 205 days).

SCB data on old age mortality

Deaths by age and year

	2007	2008	2009	2010	2011	2012	2013	2014
97	916	910	934	947	1015	1058	1018	1060
98	662	662	694	691	760	757	740	724
99	430	479	485	449	489	540	591	513
100+	712	764	778	845	822	953	908	983

Not very useful (100+).

International Database on Longevity

https://www.supercentenarians.org

Gerontology Research Group database

http://www.grg.org

GERONTOLOGY RESEARCH GROUP

GRG World Supercentenarian Rankings List

Last Updated On: Jul 18 2018 3:45PM

Numbers of Living Supercentenarians as of Last Update

Females	34
Males	2
Total	36

Validated Living Supercentenarians

Avg Age: 113 Years, 115 Days (Decimal: 113.3142)

The Human Mortality Database

https://www.mortality.org

- Contains no individual data.
- But very useful tables.

svt.se, October 2016

Människans livslängd är programmerad i arvsmassan och svår att påverka visar en ny amerikansk studie. Det finns alltså en en genetiskt bestämd gräns för våra liv. Foto: TT

120 år – människans "maximala" livslängd

Kan en människa bli hur gammal som helst eller finns det en övre gräns för vårt åldrande? Det menar forskarna bakom en ny studie som visar att människans livslängd har en naturlig gräns som är svår att överskrida.

Jeanne Calment, age 122.

SCIENCE

The New York Times

MATTER

What's the Longest Humans Can Live? 115 Years, New Study Says

Jeanne Calment died in 1997 in France at the age of 122. Pascal Parrot/Sygma, via Getty Images

By Carl Zimmer

Oct. 5, 2016

281

On Aug. 4, 1997, Jeanne Calment passed away in a nursing home in France.

Nature, 2016

nature

International journal of science

Letter | Published: 05 October 2016

Evidence for a limit to human lifespan

Xiao Dong, Brandon Milholland & Jan Vijg

Nature **538**, 257–259 (13 October 2016) | Download Citation

Dong, Milholland & Vijg, Nature 2016.

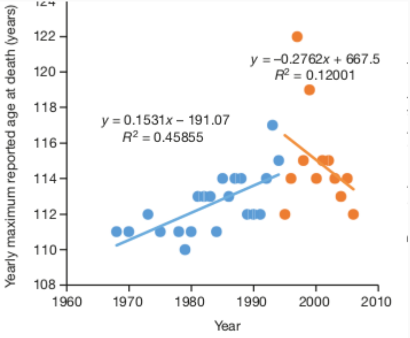


Figure 2 | Reported age at death of supercentenarian

- International Database on Longevity
- Highest age at death each year
- Linear regression with breakpoint
- Increasing trend broken!

Any problems with this "statistical analysis"?

Dong, Milholland & Vijg, Nature 2016: Problems.

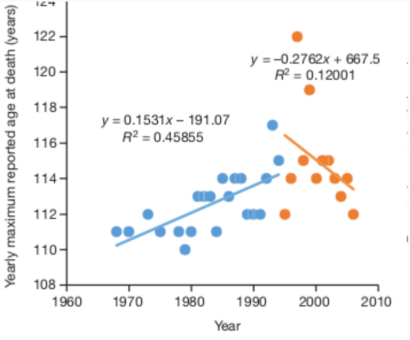
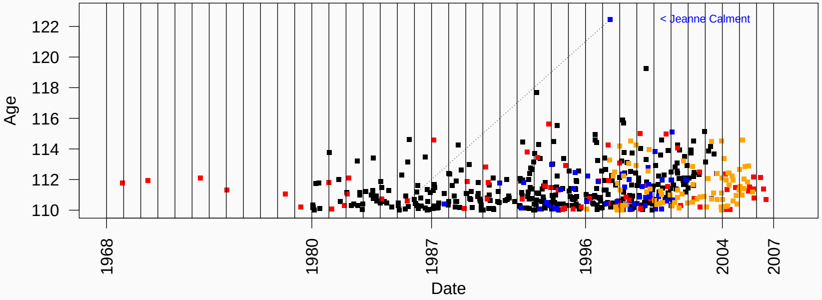


Figure 2 | Reported age at death of supercentenariar

- International Database on Longevity
- Highest age at death each year
- Linear regression with breakpoint
- Increasing trend broken!

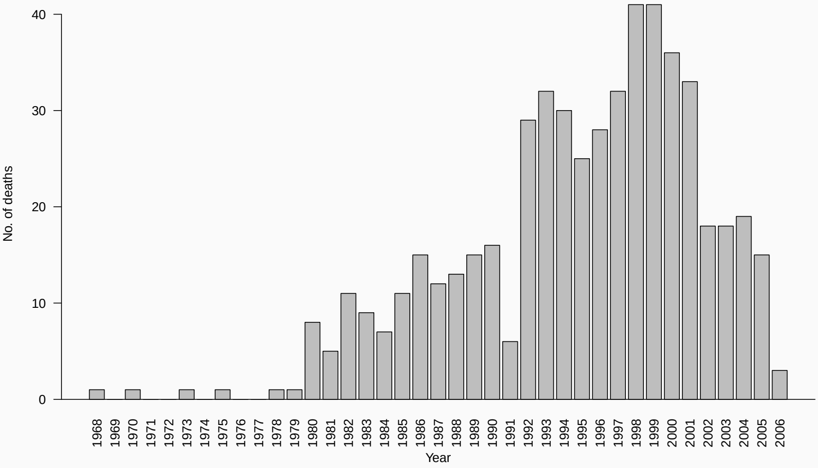
- Ad hoc choice of cutpoint.
- Very short time series to confirm a trend break.
- What about the survivors?
- Data are extreme values: full data?

The full data



Country	First	Last
UK	1968	2006
USA	1980	2003
France	1987	2003
Japan	1996	2005

Number of deaths by year



Nature, 2017

nature

International journal of science

Brief Communications Arising | Published: 28 June 2017

Questionable evidence for a limit to human lifespan

Adam Lenart & James W. Vaupel

Nature **546**, E13–E14 (29 June 2017) | Download Citation

Nature, 2017

Contesting the evidence for limited human lifespan
Nicholas J. L. Brown, Casper J. Albers & Stuart J. Ritchie

Dong *et al.* reply
Xiao Dong, Brandon Milholland & Jan Vijg

Many possible maximum lifespan trajectories
Bryan G. Hughes & Siegfried Hekimi

Dong *et al.* reply
Xiao Dong, Brandon Milholland & Jan Vijg

Is there evidence for a limit to human lifespan?
Maarten P. Rozing, Thomas B. L. Kirkwood & Rudi G. J. Westendorp

Dong *et al.* reply
Xiao Dong, Brandon Milholland & Jan Vijg

Questionable evidence for a limit to human lifespan
Adam Lenart & James W. Vaupel

Dong *et al.* reply
Xiao Dong, Brandon Milholland & Jan Vijg

Maximum human lifespan may increase to 125 years
Joop de Beer, Anastasios Bardoutsos & Fanny Janssen

Dong *et al.* reply
Xiao Dong, Brandon Milholland & Jan Vijg

Rootzén and Zholud

Two serious blows:

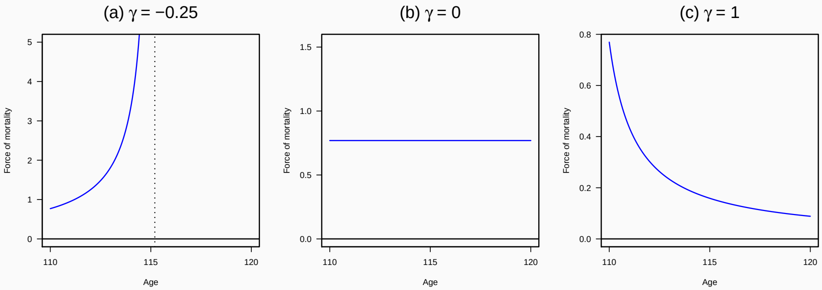
1. Extreme values do not behave like “normal” data.
2. The data suffer from length bias.

and one conclusion:

1. There is no aging after age 110!

The Generalized Pareto (GP) distribution

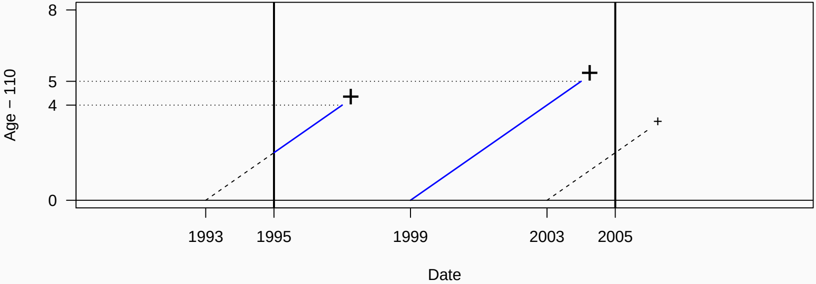
$$h(x;(\gamma,\sigma)) = \frac{1}{\sigma(1+\gamma x/\sigma)_+}$$



1. "Life is short"; (b) "Life is unlimited but short"; (c) "Life is unlimited".

Length-biased sampling

Data are *left-truncated* and *right-truncated*:



$$\mathcal{L} = \frac{\mathcal{P}(X_1 = 4)}{\mathcal{P}(2 < X_1 \leq 12)} \times \frac{\mathcal{P}(X_2 = 5)}{\mathcal{P}(X_2 \leq 6)}$$

Inverse Probability Weighting (Horwitz-Thomson, *JASA* 1952.)

Critique of Dong et. al. by Rootzen & Zholud

- The apparent trend break in the figure is an artifact caused by inappropriate combination of data from different time periods.
- The conclusion "our data strongly suggest that the duration of life is limited" is based on wrong and misleading analysis.

Results, Rootzen & Zholud

- "Life is unlimited but short": $\gamma = 0$, $\sigma = 1.34$
  - No aging after age 105.
  - Expected remaining life at age $t, t > 105$: 1.34 years.
  - Probability of surviving one year: 47 per cent.
- *Interpretation:* At each birthday after 105, flip a coin. If heads, survive until next birthday, if tails, die before next birthdate.
- No difference between countries, sexes, birth cohorts.

James Vaupel, later

"I was outraged that Nature, a journal I highly respect, would publish such a travesty."

How could this happen?

Not uncommon:

- No statisticians involved.
  - Demographic research is performed by people from sociology, psychology, economy, etc. with inadequate statistical training.
  - the same holds for editors of journals from the same fields.
- Too powerful statistical software.
  - "Who needs a statistician?"
  - "I have read the manual."
- Failure to understand the GIGO principle ("Garbage In, Garbage Out").
  - There is always some Garbage Out.

See http://capa.ddb.umu.se/ds

Data from FOB and Lisa

Birth information (11 566 545 individuals):

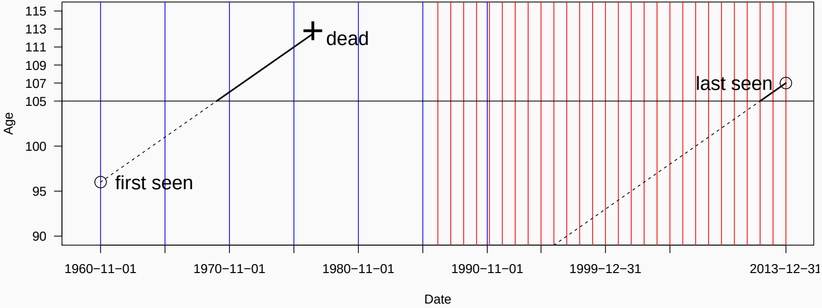
LINNEID	FODELSEAR	FODELSEKVARTAL	KON
10001430	1940	2	1
12424305	1945	3	2
10966939	1946	1	1

Death information (4 772 378 individuals):

LINNEID	DODSDAT
6	20130127
26	20130923
32	20051001

Presence information?

Presence information



Swedish data, 110+

There are 23 women and 4 men.

The Gompertz distribution

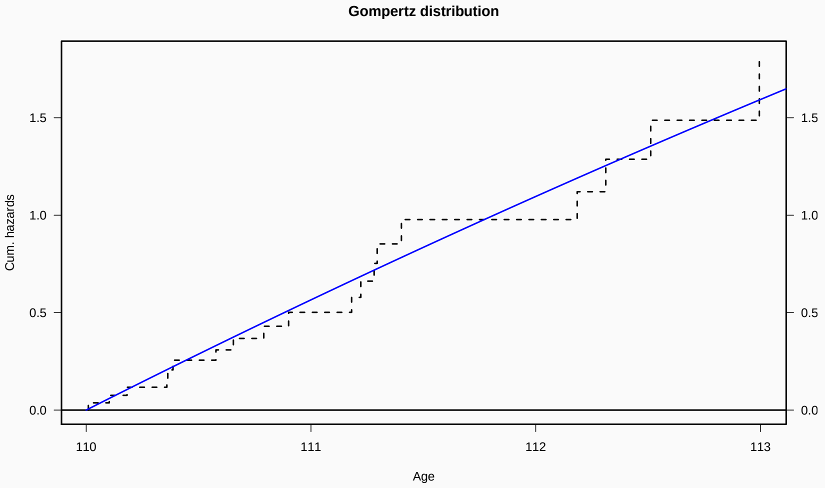
Hazard function:

$$h(t;\alpha,r) = \alpha \exp(rt), \quad t > 0$$

If $r = 0$:

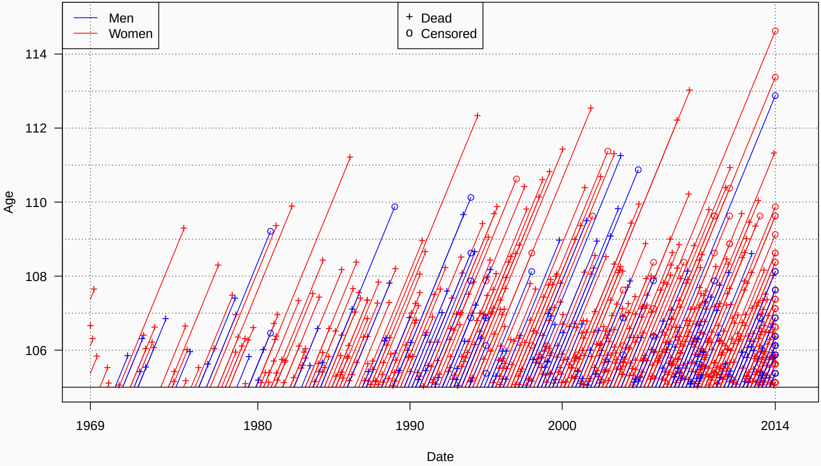
$$h(t;\alpha,0) = \alpha, \quad t > 0$$
$$H(t;\alpha,0) = \alpha t, \quad t > 0.$$

Cumulative hazards beyond age 110



r = -0.064 (0.239), mean = 1.713

Sweden, 105+



Men
Women
+ Dead
o Censored
114
112
110
108
106
Age
1969
1980
1990
2000
2014
Date

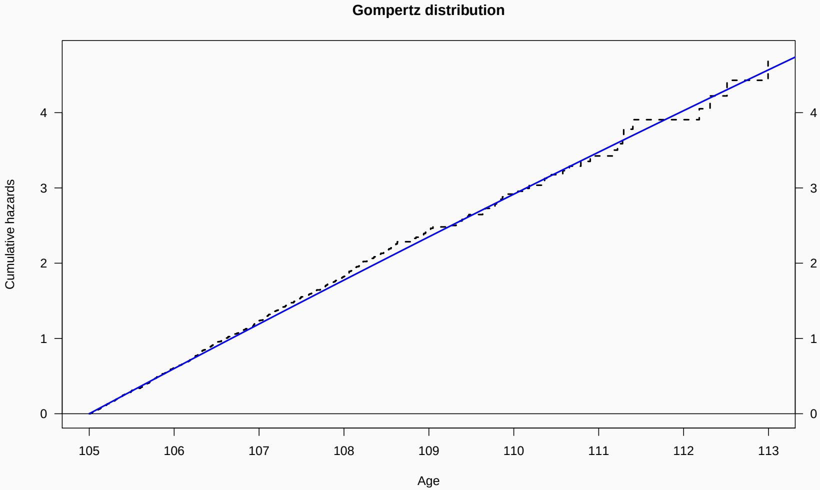
Analysis, 105+

Covariate	Mean	Coef	Risk Ratio	S.E.	L-R p
sex					0.093
woman	0.851	0	1	(reference)	
man	0.149	-0.169	0.844	0.103	
I(birthdate - 1900)	-5.284	-0.005	0.995	0.003	0.193
Baseline parameters					
rate		-0.014	0.986	0.026	0.583
log(level)		-0.503	0.605	0.054	0.000
Events	846	TTR	1426		
Max. Log Likelihood	-1285				

Constant hazard $= 0.605$.

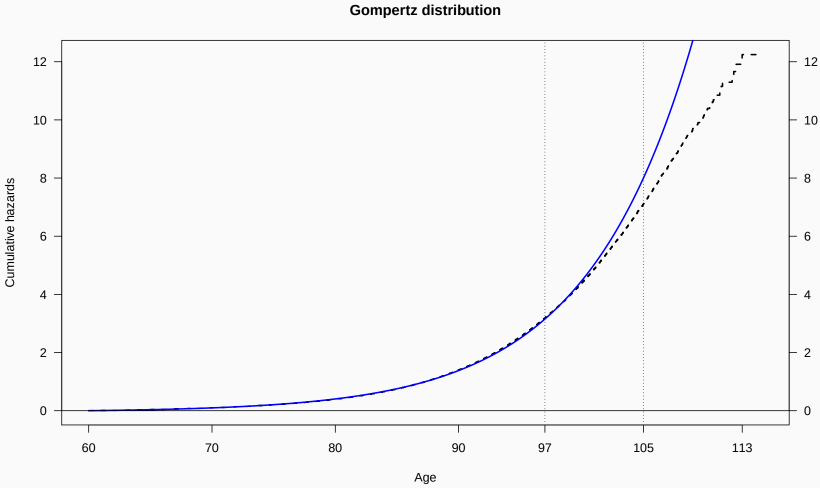
Mean $= 1/0.605 = 1.65$ years.

Baseline hazard, 105+



$r = -0.014$ (0.026)

In perspective, 60+



$r = 0.115$, $\exp(r) = 1.122$.

Italy, 105+ 2009–2015 (Science June 29, 2018)

HUMAN DEMOGRAPHY

The plateau of human mortality: Demography of longevity pioneers

Elisabetta Barbi[1*], Francesco Lagona[2], Marco Marsili[3], James W. Vaupel[4,5,6,7], Kenneth W. Wachter[8]

Theories about biological limits to life span and evolutionary shaping of human longevity depend on facts about mortality at extreme ages, but these facts have remained a matter of debate. Do hazard curves typically level out into high plateaus eventually, as seen in other species, or do exponential increases persist? In this study, we estimated hazard rates from data on all inhabitants of Italy aged 105 and older between 2009 and 2015 (born 1896–1910), a total of 3836 documented cases. We observed level hazard curves, which were essentially constant beyond age 105. Our estimates are free from artifacts of aggregation that limited earlier studies and provide the best evidence to date for the existence of extreme-age mortality plateaus in humans.

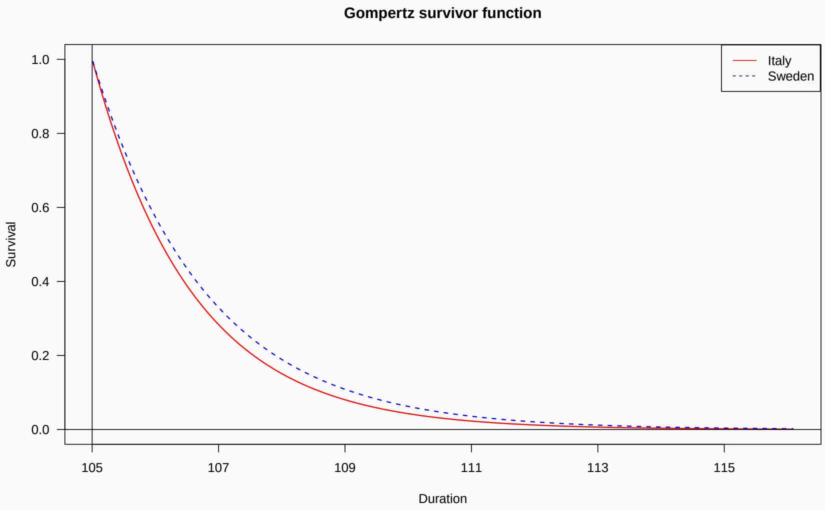
Survival to extreme ages tests the limits of evolutionary demographic potential. Here

tality curve levels out, it is said to reach a plateau. The findings for humans are consistent with dis-

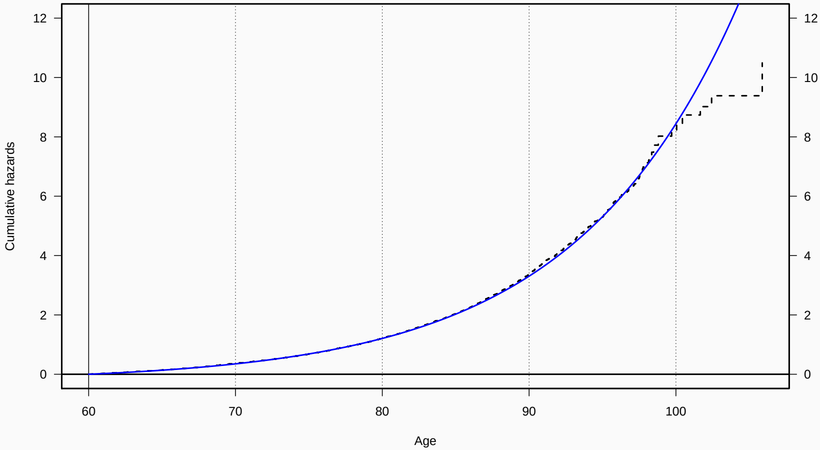
Italy results

Covariate	Mean	Coef	Risk Ratio	S.E.	L-R p
I(cohort - 1900)	6.120	-0.016	0.984	0.009	0.076
sex					0.561
woman	0.886	0	1	(reference)	
man	0.114	0.034	1.035	0.058	
Baseline parameters					
rate		0.013	1.013	0.017	0.444
log(level)		-0.399	0.671	0.073	0.000
Events	2883	TTR	4639		
Max. Log Likelihood	-4250				

Sweden and Italy



Skellefteå-Umeå data, birth cohort 1810-1850, ages 60+

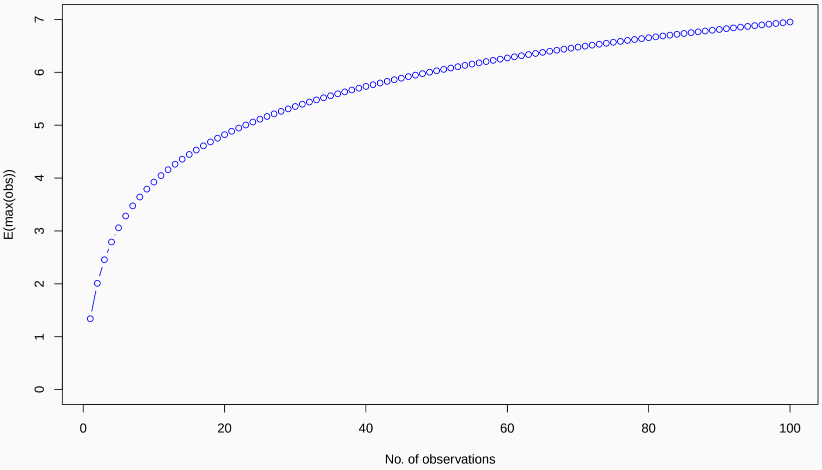


Conclusion

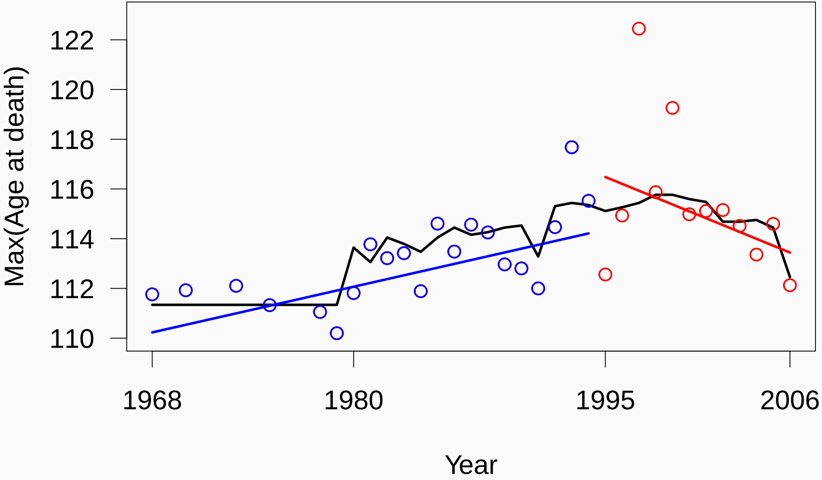
- No evidence of limits to human life
  - Not rejecting a null hypothesis means no information
- The mortality plateau after age 105 seems universal.
- Be aware of risks of sampling bias.
- Ditto of informative censoring.
- The aging process
  - begins at birth, and
  - ends at age 105

Extra material

Expectation of extremes



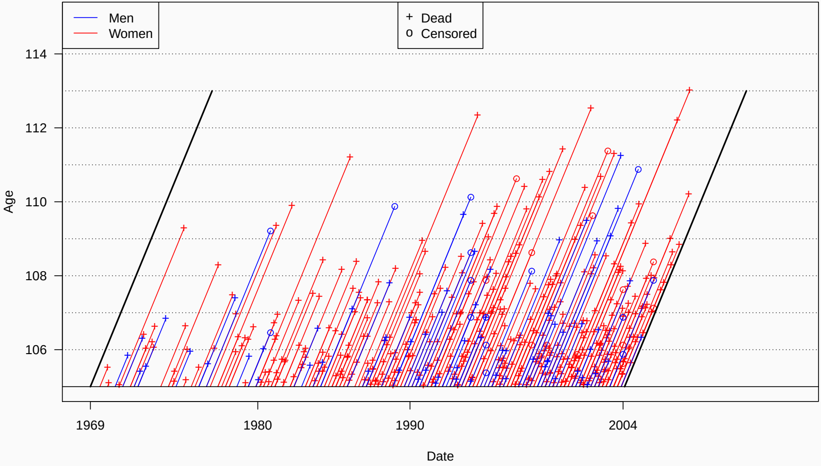
The original plot, expectation added



Analysis, no censored observations, 105+

Covariate		Mean	Coef	Risk Ratio	S.E.	L-R p
sex						0.340
	woman	0.878	0	1	(reference)	
	man	0.122	0.099	1.104	0.102	
I(birthdate - 1900)		-6.560	0.011	1.011	0.004	0.003
Baseline parameters						
log(scale)			0.287	1.332	0.040	0.000
log(shape)			0.072	1.075	0.027	0.007
Events		846	TTR	1152		
Max. Log Likelihood		-1100				

Cohort version, 105+



432 women, 83 men.

Cohort Analysis

Covariate	Mean	Coef	Risk Ratio	S.E.	L-R p
cohort					0.086
(1969,1985]	0.158	0	1	(reference)	
(1985,1995]	0.376	-0.291	0.747	0.131	
(1995,2004]	0.465	-0.166	0.847	0.124	
sex					0.042
woman	0.827	0	1	(reference)	
man	0.173	-0.259	0.772	0.131	
Baseline parameters					
rate		0.041	1.041	0.033	0.217
log(level)		-4.617	0.010	3.498	0.187
Events	487	TTR	819		
Max. Log Likelihood	-735				

Cumulative hazards by period