# A best practices composite lifetable for US states

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**Abstract**

We calculate a preliminary series of best-possible lifetables for the United States from 1959-2004, defined as the age-specific aggregate of the lowest observed age-cause specific death rates among the 50 states and the District of Columbia for each year. This synthetic best practices lifetable shows a gradual increasing trend over the period, on average 1.9 and 2.2 years higher than the highest state life expectancy in each year for males and females, respectively. We argue that the US states best practices lifetable is a useful guage of mortality.

## Introduction

The question of limits to life expectancy is fundamental to demography, but it is also practical when projecting mortality. Mortality reductions in past decades have been steady in many populations, and at times linear, which tends to guide projections into predicting the same sort of progress far into the future. Most past attempts to place limits on such projections were shown to be overly conservative within a short period of years (Oeppen et al. 2002). However, many simple mortality projections will send life expectancy scenarios to very high levels that for a given population may seem unimaginable. In some cases, one seeks an external population that

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has already achieved a life expectancy as high as that produced by a model, and this gives some assurance that the projection is possible. Japan assumes this role in many cases today. In 2012 life expectancy for Japanese females was 86, while for US females it was 81 (Human Mortality Database 2015). If a US projection turns out to reach 86 we at least know that this is indeed possible.

The desire for such external references explains part of the interest in the historical development of world record life expectancy (Oeppen et al. 2002). The maximum life expectancy from a set of populations shows what other populations may one day achieve due to diffusion in practices, technology, and wellbeing (Vallin and Meslé 2010). The vanguard life expectancy is calculated based on mortality rates undifferentiated by cause of death, which may not provide an omnibus signal of what may eventually develop. While the force of mortality governs the lifetable, there is a substantive rationale to conceive of this force as a composite of cause-specific forces of mortality. Vallin and Meslé (2008) separate trends in life expectancy by causes of death, explained in terms of an epidemiological transition that unfolds in progressive stages with respect to particular technologies and risk factors in recent history.

The level and timing of cause-specific responses to particular technological or well-being improvements varies between populations. Therefore, the lowest observed all-cause force of mortality is not necessarily composed of the lowest cause-specific forces of mortality, which means that the vanguard life expectancy may not reflect the best mortality possible given current conditions over a set of populations. For instance, the lowest rate of suicide and heart disease at age 45 will not necessarily be found in the same population. As an alternative to vanguard life expectancy, one could create cause-specific low-mortality benchmarks, or more synthetically, combine the lowest mortality observed by age and cause into a hybrid minimum mortality schedule. This synthetic low mortality lifetable— hybrid with respect to reference population over age and cause— was already suggested by Wunsch (1975) and Vallin and Meslé (2008). These authors investigated trends at the national-level. We refer to such hybrid minimum lifetables as best practices lifetables. *eikemo2014* use the term "best practices" in a similar sense of an ideal mix of condtions, but do so via combining particular risk factors with their estimated mortality impacts to produce best case scenarios. The end effect is quite similar, to the extent that either estimation strategy shows what society could acheive given perfect diffusion of some defintion of best conditions. In the case of a best practices lifetable, we condition on mortality outcomes only, making the endeavor much simpler in practice.

National populations are heterogeneous with respect to many factors, both observed and unobserved, that affect cause-spectific mortality rates. This does not make international mortality comparisons futile, but it may make perfect convergence unimaginable even in the very long run. This is the case for both all cause and cause-specific mortality. When projecting mortality for a given country, we wonder whether mortality from an external population, or set of populations, is the best “sanity check” for mortality forecasts. For this reason, we propose a minimum mortality trend for the United States calculated on the basis of its own territorial subdivisions, the 50 states plus the District of Columbia. This choice limits the sources of unaccounted for heterogeneity in international comparisons, and it also conveniently homogenizes data sources. To be clear, we do not necessarily propose using a trend in best practices mortality as a component of coherent mortality forecasts, and we do not undertake such an exercise. Instead, we view the U.S. best practices mortality as indicative of the potential already present in the U.S., a special kind of “nowcast”.

## Data and methods

All death count data come from the public NCHS mortality microdata files (National Center for Health Statistics 1959–2004). Population denominators come from a beta version of the U.S. States project of the Human Mortality Database (Human Mortality Database 2015). Further processing of population counts into exposures is done according to the HMD Methods Protocol, and all-cause lifetables were calculated by single ages (Wilmoth et al. 2007). Death counts for causes were aggregated into quinquennial age groups by year and sex for eleven large groups that minimize disruptions between ICD transitions, and then converted to fractions. Fractions were then multiplied into the single-age all-cause death rates. The eleven causes of death considered in this abstract version are displayed in Table 1, with their relative percentages.

Table 1: Eleven causes of death considered in the current study version, percentages.

| | Females | Males |
|---:|---:|---:|
| All other | 29.91 | 33.95 |
| Breast | 3.73 | 0.03 |
| Cardiovascular | 38.49 | 38.10 |
| Cerebrovascular | 10.50 | 6.84 |
| Lung | 3.55 | 6.50 |
| Other Cerebrovascular | 0.33 | 0.28 |
| Other Malignant Neoplasms | 11.01 | 9.83 |
| Other smoking | 0.57 | 1.36 |
| Prostate | | 2.25 |
| Stomach | 0.67 | 0.87 |
| Uterus | 1.25 | |

One caveat of calculating a best practices lifetable is that stochastic zeros occur in particular ages and causes, especially among small populations. The exercise of selecting the minimum death rate for a given age and cause will tend to collect stochastic zeros, producing an excessively optimistic best practices life expectancy. We therefore smooth all death rates using the `MortalitySmooth` package (Camarda 2012) in `R`. The age-period matrix of death rates for each state and sex is smoothed over both margins, fractions are then recalculated, a multiplied into the smoothed all-cause death rates. Finally, we calculate lifetables for both states and best practices lifetables using HMD methodology.

We decompose differences in state life expectancy from the best-practices life expectancy using the pseudo-continuous method proposed by Horiuchi et al. (2008). We prefer this method because it allows for defining life expectancy as a direct function of age-cause-specific rates, $M_{(x,c)}$, thereby eliminating some artifacts present in other methods. Results are summarized by ages, causes and states and can be interpreted directly as the the total lag in years of life expectancy due to excess mortality (anything greater than the minimum) in the given margin.[1]

# Preliminary results

All results at this time are preliminary, but we can report broad trends at this time.[2]

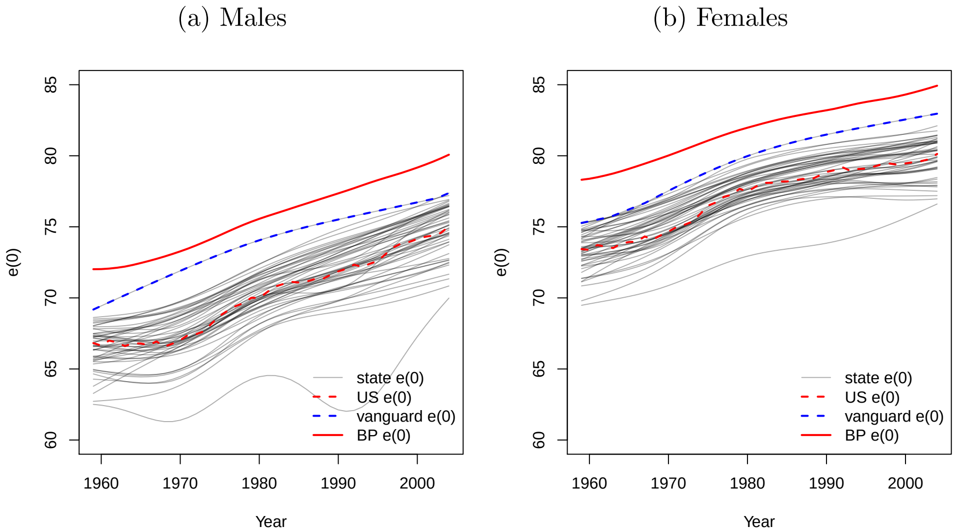
## Life expectancy trends

Most states display irregular gradual increasing trends over the 45 years considered, except for males in the District of Columbia, which has been recovering strongly since the 1990s, due both to secular improvements and compositional change. The US aggregate trend is bouncier because death counts were not smoothed, and its rank position among states varies due in part also to compositional changes between states. The vanguard state life expectancy for males is Hawaii until the two most recent years of observation (2003-2004), where Minnesota has taken the lead. For females, the Minnesota is vanguard until 1963, followed by North Dakota for five years,

[1] In the final version we may opt to further separate trends from initial differences using the decomposition method recently proposed by Jdanov and Shkolnikov (2014).

[2] The final results will differ in the following ways. At this time we have calculated results using 11 causes of death that were previously used in a different research project, and this will change to 30 causes to be consistent and comparable with Vallin and Meslé (2008). Including more causes will increase the best practices life expectancy level. We will also include estimates through 2012 or 2013. At this time, we were only able to produce results through 2004, because geographic information is suppressed in the microdata for later years. This information is available in secure Research Data Centers, where we will produce cause fractions and all-cause lifetables for the most recent decade.

Figure 1: Trends in US, vanguard, best practices, and state life expectancies ($e(0)$), 1959-2004.




and then Hawaii for the rest of the series until 2004. The vanguard trend for females has the same overall shape as the cluster of individual state trends, but for males the time trend in vanguard, ergo Hawaiian, life expectancy was different from the bulk of states.

For both males and females, the best practices trend is on average 2 years higher than the vanguard trend, and its progress is steadier than either the vanguard or national trends, as well as most individual states. The best practices trend has increased each year for males and females, though faster for males. The average annual improvement for males has been 0.1790 years of $e(0)$ per annum, compared with 0.1785 for the male national average life expectancy. The respective rates of improvement for females have been 0.1470 and 0.1456. It is convenient and telling that the respective medium term average rates of improvement between national and best practices life expectancy match so closely, despite the best practices trend having a much more stable trajectory. This artifact may provide some support to conceiving of the best practices trend as indicative of where the U.S. is going in the coming decades.

If we take the mean rate of improvement for national or best practice trends, and compare it with the means of each series, we can roughly conclude that the best practices trend in year $t$ is a decent estimate of the national life expectancy in 30 or so years. This time lag is valid for the present series, but will vary depending on the number of cause groups that enter into the selection of minimum mortality rates. Clearly, if the population units were counties rather than states, the level of best practices life expectancy would increase even further, but we opine that cause-specific smoothing at the county level is more of a modelling gesture than sound practice, due to very low counts of deaths in most counties in the U.S. In the final paper we will aim to test the cause set proposed by Vallin and Meslé (2008) and compare it with other reasonable configurations for the U.S., and so recommend a rule of thumb grouping.

### State differences by cause

We decompose the state departures in life expectancy from the best practice trend in each year and sex, over both age and cause. Part of the attraction of decomposing with respect to the best practices life expectancy is that contributions are always of the same sign, which makes interpretation of the heatmap more intuitive. Deeper shades of red indicate larger departures. In Figure 2 we aggregate over age and average within decades to summarize the total contribution to the departure from best practices.[3] Major causes of death are in rows, and decades are organized in columns.

For the case of cardiovascular disease and other causes, grouping departures into the 2+ group blends out much interstate variation, since some contributions range as high as 4 years, but broad patterns are still visible.[4]

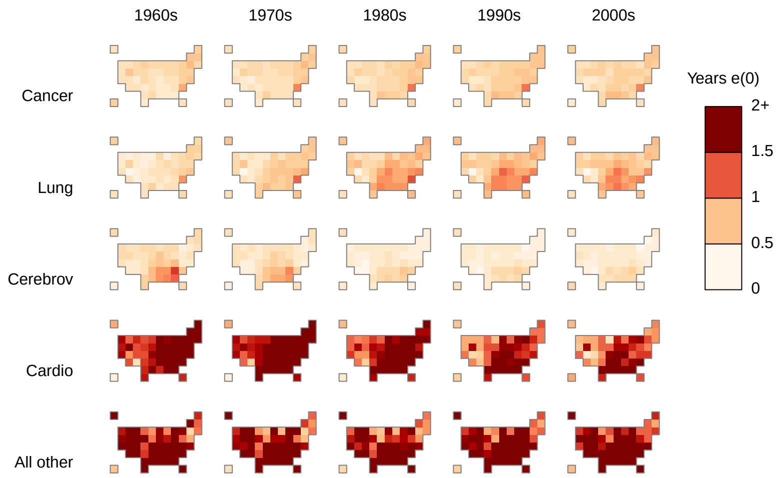
Since the cause groupings available at the time of submission are not the final groupings, and because the causes included in the study contribute such varying magnitudes to state differences, trends are dominated by Cardivascular diseases and the large aggregate group of all other causes. The 11 original causes were grouped into five so as to make state patterns more visible. More commentary to come at a later date.

[3]The 2000s trend is based on the average for the years 2000-2004 only.

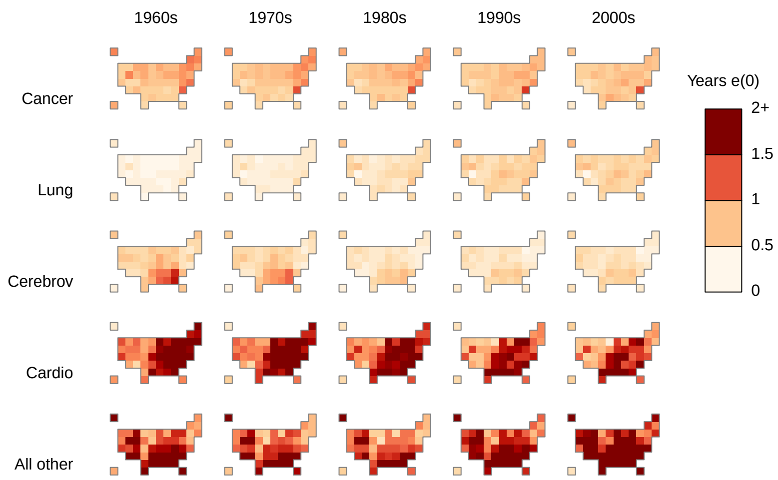
[4]This visual display may be significantly adapted when we add more causes to the decomposition. We will also do a similar small multiples display for grouped age patterns.

Figure 2: State departures from vanguard $e(0)$ by large cause groups, 1959-2004.

(a) Males




(b) Females




## References

Carlo G. Camarda. MortalitySmooth: An R package for smoothing Poisson counts with P-splines. *Journal of Statistical Software*, 50(1):1–24, 2012. URL `http://www.jstatsoft.org/v50/i01/`.

Shiro Horiuchi, John R Wilmoth, and Scott D Pletcher. A decomposition method based on a model of continuous change. *Demography*, 45(4):785–801, 2008.

Human Mortality Database. University of California, Berkeley (USA) and Max Planck Institute for Demographic Research (Germany), 2015. Available at www.mortality.org or www.humanmortality.de (data downloaded on July 10, 2014).

D.A. Jdanov and V.M. Shkolnikov. An r-script for the assessment of the cross-sectional and the longitudinal components of a difference between two values of an aggregate demographic measure by contour replacement. Technical report, Max Planck Institute for Demographic Research, 2014.

National Center for Health Statistics. Data Files, Mortality (1959–2004). machine readable data file and documentation, 1959–2004. [downloaded in 2014].

Jim Oeppen, James W Vaupel, et al. Broken limits to life expectancy. *Science*, 296(5570):1029–1031, 2002.

J. Vallin and F. Meslé. Espérance de vie: peut-on gagner trois mois par an indéfiniment? *Population et sociétés*, (473):1–4, 2010.

Jacques Vallin and France Meslé. Minimum mortality: A predictor of future progress? *Population-E*, 63(04):557–590, 2008.

John R Wilmoth, K Andreev, D Jdanov, Dana A Glei, C Boe, M Bubenheim, D Philipov, V Shkolnikov, and P Vachon. Methods protocol for the human mortality database. Technical report, University of California, Berkeley, and Max Planck Institute for Demographic Research, Rostock., 2007. URL `http://mortality.org[version31/05/2007]`.

Guillaume Wunsch. A minimum life-table for europe. *European Demographic Information Bulletin*, 5(1):2–10, 1975.