Decomposition techniques in population health research

José Manuel Aburto
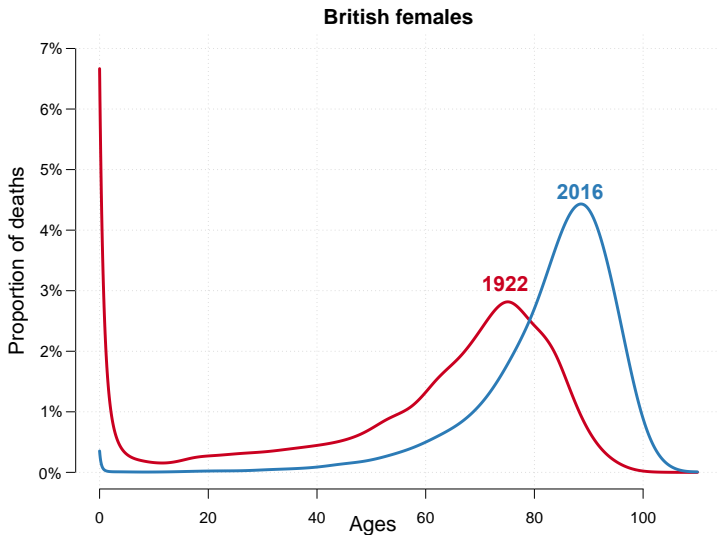
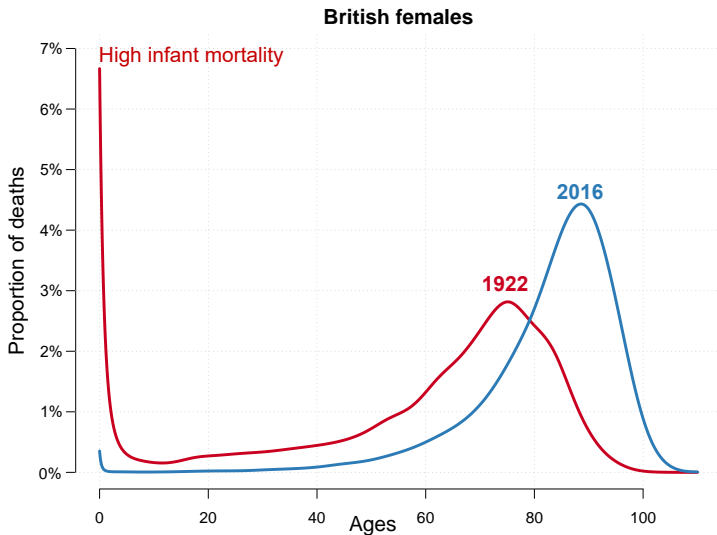🐦 @jm_aburto

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SCHOOL OF
DEMOGRAPHY

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SDU

UNIVERSITY OF OXFORD
DEPARTMENT OF
SOCIOLOGY
LEVERHULME CENTRE
FOR DEMOGRAPHIC SCIENCE

The
British
Academy

What is lifespan inequality?

British females

What is lifespan inequality?

British females

What is lifespan inequality?

British females

High infant mortality

Shifting with life expectancy increasing from **58.9** to **82.9** years

2016

1922

Proportion of deaths

Ages

What is lifespan inequality?

British females
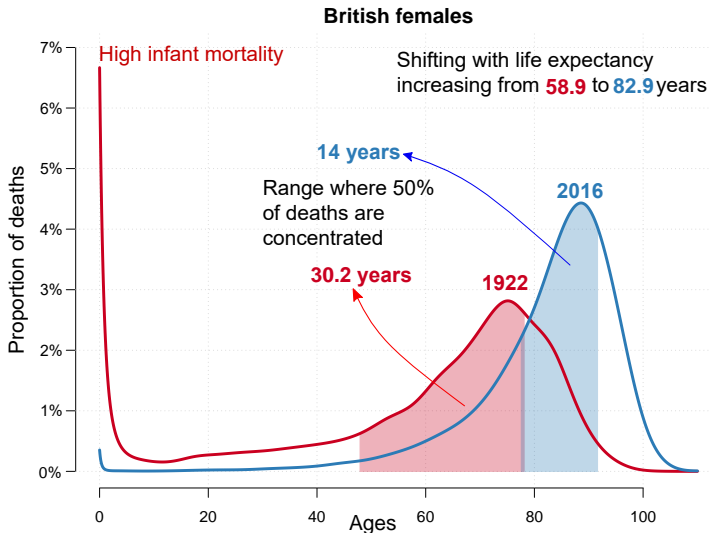
Why studying lifespan inequality?

► **Complements** life expectancy.

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▶ Reflects **individual uncertainty** in the timing of death (micro).

Why studying lifespan inequality?

► **Complements** life expectancy.

► Reflects **individual uncertainty** in the timing of death (micro).

► **Heterogeneity** in underlying population health (macro).

Spread-Allocation-Timing

Routledge
Taylor & Francis Group

Check for updates

Latin American convergence and divergence towards the mortality profiles of developed countries

Jesús-Adrián Alvarez [1], José Manuel Aburto [1,2] and
Vladimir Canudas-Romo [3]

[1]University of Southern Denmark, [2]Max Planck Institute for Demographic Research, [3]Australian National
University

It is uncertain whether Latin America and Caribbean (LAC) countries are approaching a single mortality regime. Over the last three decades, LAC has experienced major public health interventions and the highest number of homicides in the world. However, these interventions and homicide rates are not evenly shared across countries. This study documents trends in life expectancy and lifespan variability for 20 LAC countries, 2000–14. By extending a previous method, we decompose differences in lifespan variability between LAC and a developed world benchmark into cause-specific effects. For both sexes, dispersion of amenable diseases through the age span makes the largest contribution to the gap between LAC and the benchmark. Additionally, for males, the concentration of homicides, accidents, and suicides in mid-life further impedes mortality convergence. Great disparity exists in the region: while some countries are rapidly approaching the developed regime, others remain far behind and suffer a clear disadvantage in population health.

Standard deviation and life expectancy differences in for LAC countries and the benchmark trajectory, Males 2000-2014
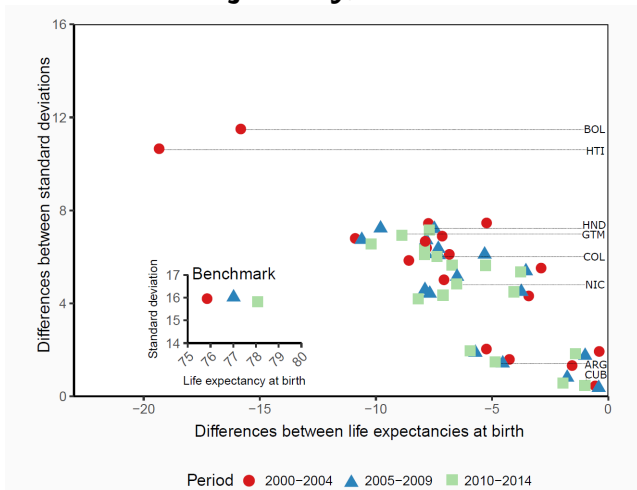
Extension of SAT decomposition to SD

$$\sigma_l - \sigma_b = spread + allocation + timing + joint,$$
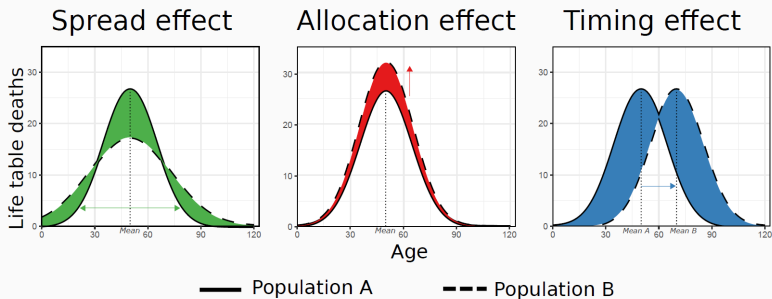
$$spread = K \sum_{c=1}^{C} p_{c,b}(\sigma_{c,l}^2 - \sigma_{c,b}^2)$$

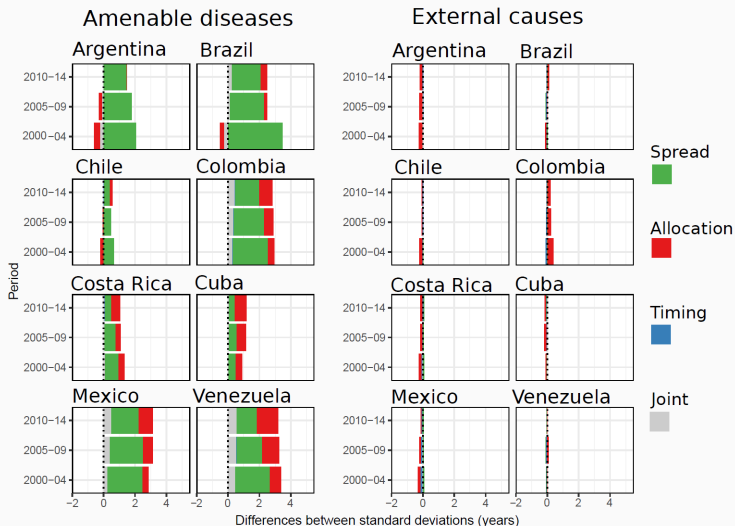$$allocation = K \sum_{c=1}^{C} (p_{c,l} - p_{c,b})(\sigma_{c,b}^2 - \bar{x}_{c,b}^2)$$

$$timing = K \sum_{c=1}^{C} p_{c,b}(\bar{x}_{c,l}^2 - \bar{x}_{c,b}^2)$$

$$joint = K \sum_{c=1}^{C} (p_{c,l} - p_{c,b})[(\sigma_{c,l}^2 - \sigma_{c,b}^2) - (\bar{x}_{c,l}^2 - \bar{x}_{c,b}^2)].$$
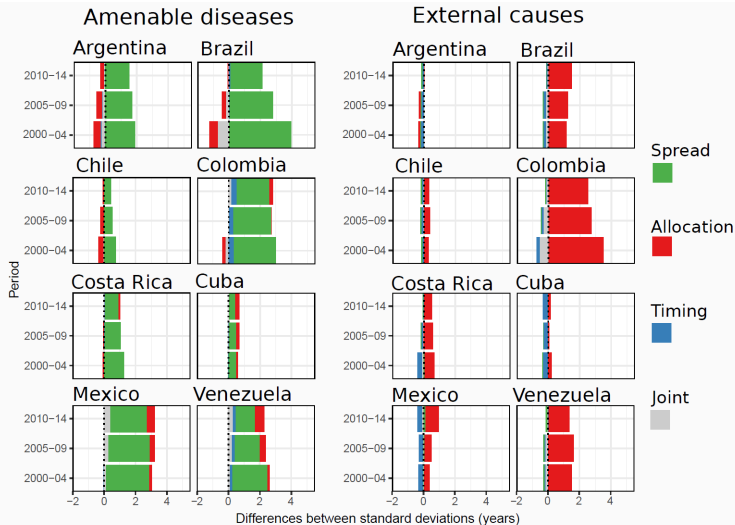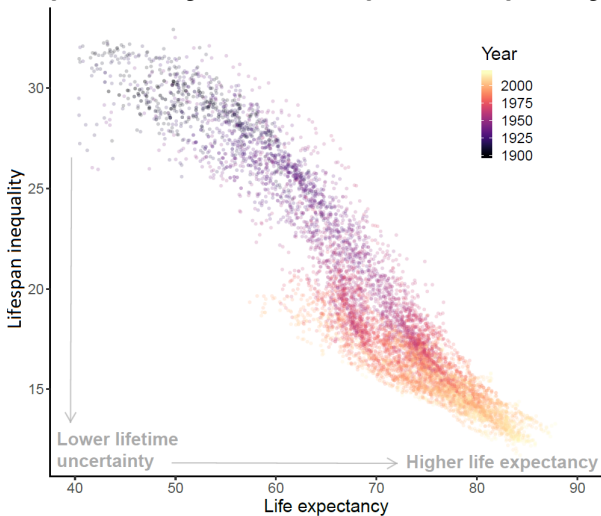
Extension of SAT decomposition to SD

Spread effect   Allocation effect   Timing effect

—— Population A   - - - Population B

Decomposition differences for females

Decomposition differences for males

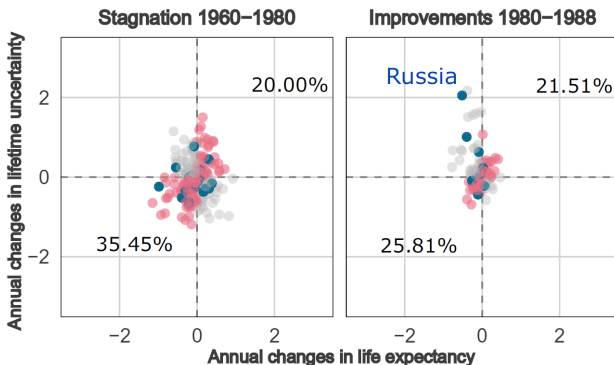# Life expectancy and lifespan inequality (σ)

Edwards and Tuljapurkar, PDR (2005); Smits & Monden, Soc. Sci. Med. (2009); Vaupel et al, BMJ Open (2011)

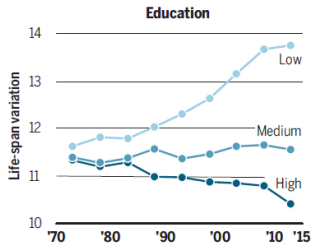**We are beginning to see this relationship reversed**

We are beginning to see this relationship reversed

Annual changes in life expectancy and lifespan inequality in Central and Eastern European countries.
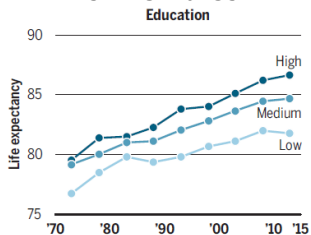
Finnish females

van Raalte et al, Science (2018)

Finnish females

- ▶ **Denmark**. Bronnum-Hansen, BMJ Open (2017)
- ▶ **USA**. Sasson, Demography (2016)
- ▶ **Scotland**. Seaman et al, SSM Popul. Health (2016)
- ▶ **Spain**. Permanyer et al, Demography (2019)

van Raalte et al, Science (2018)

Finnish females

Life expectancy / Education

Life-span variation / Education
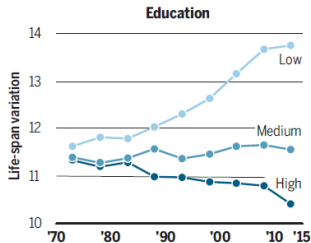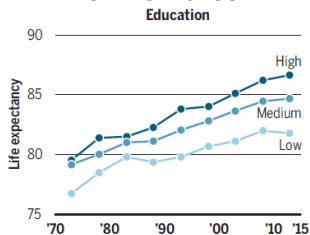
van Raalte et al, Science (2018)

▶ **Denmark**. Bronnum-Hansen, BMJ Open (2017)
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▶ **Scotland**. Seaman et al, SSM Popul. Health (2016)
▶ **Spain**. Permanyer et al, Demography (2019)

Can we use **formal demography** to understand these trends/differences?

Life expectancy at birth

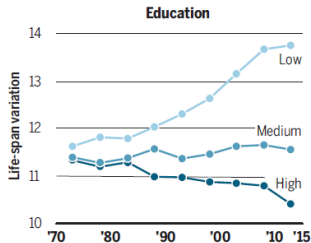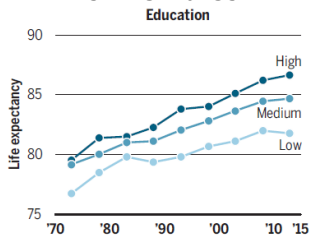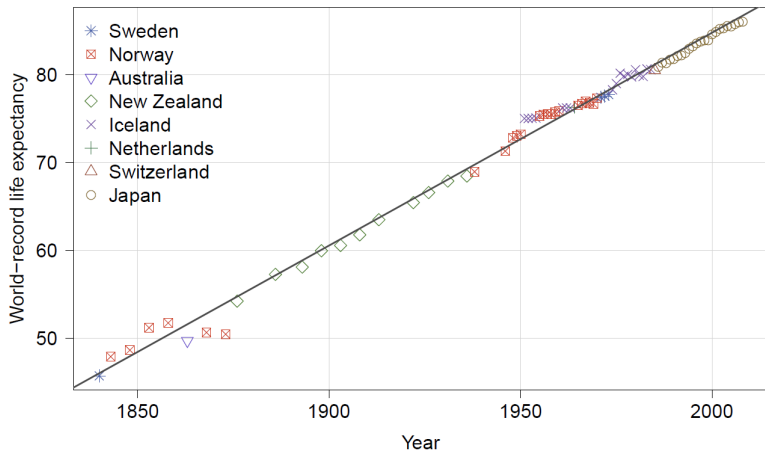World-record life expectancy, 1840–2000. Source: Oeppen and Vaupel (2002)

Life expectancy at birth

The change over time in e_o is given by

$$\frac{\partial e_o}{\partial t} = \int_0^\infty \rho(x)\underbrace{\mu(x)\ell(x)}_{d(x)}\,e(x)dx = \int_0^\infty \rho(x)w(x)dx$$

where

$$\rho(x) = -\frac{\partial\mu(x)/dt}{\mu(x)}$$

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$$\rho(x) = -\frac{\partial \mu(x)/dt}{\mu(x)}$$

$\dot{e}_o =$ **is a weighted total of rates of mortality improvement** ρ (Vaupel & Canudas Romo, 2003)

Lifetable entropy

$$\bar{H} = -\frac{\int_0^\infty \ell(x) \ln[\ell(x)]dx}{\int_0^\infty \ell(x)dx}, \text{ (Leser 1955, Keyfitz 1977, Demetrius 1979)}$$

Lifetable entropy

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$$= \frac{\int_0^\infty d(x)e(x)dx}{\int_0^\infty \ell(x)dx}, \text{ (Vaupel 1989, Goldman \& Lord 1986, Hokkert 1987)}$$

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$$= \frac{\int_0^\infty d(x) e(x) dx}{\int_0^\infty \ell(x) dx}, \text{ (Vaupel 1989, Goldman \& Lord 1986, Hokkert 1987)}$$

$$= \frac{e^\dagger}{e_o}, \text{ (Vaupel \& Canudas-Romo 2003)}$$

where $e^\dagger$ is the average life lost at death, a measure of absolute lifespan inequality.

The change over time in lifetable entropy
is given by

$$\frac{\dot{\bar{H}}}{\bar{H}} = \frac{\dot{e}^{\dagger}}{e^{\dagger}} - \frac{\dot{e}_o}{e_o},$$ *(Fernández & Beltrán-Sánchez 2015 TPB)*

$$\dot{e}^{\dagger} = \int_0^{\infty} \rho(x) w(x) \Big(\underbrace{H(x) + \bar{H}(x)}_{\text{Cumulative hazard + entropy from age } x} - 1 \Big) dx$$

$$\dot{e}^\dagger = \int_0^\infty \rho(x) w(x) \big(\underbrace{H(x) + \bar{H}(x)}_{\text{Cumulative hazard + entropy from age } x} - 1 \big) dx$$

$\dot{e}^\dagger =$ **weighted total of rates of mortality improvement** ρ

Wagner 2010, Aburto et al 2019 Dem Res

We have all the ingredients

$$\frac{\dot{\bar{H}}}{\bar{H}} = \frac{\dot{e}^{\dagger}}{e^{\dagger}} - \frac{\dot{e}_o}{e_o}$$

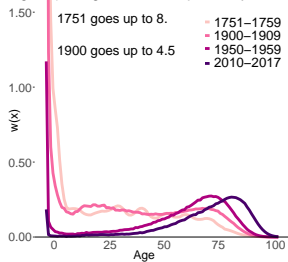$$\dot{\bar{H}} = \int_0^\infty \rho(x) \underbrace{w(x)\,W(x)}_{g(x)}\,dx$$

$$\dot{\bar{H}} = \int_0^\infty \rho(x) \underbrace{w(x) W(x)}_{g(x)} dx$$

Key point: change in $\bar{H}$ over time is a weighted total of ρ

Aburto et al 2020 PNAS

Swedish females

Fig. 2A) Weights for life expectancy

1751 goes up to 8.

1900 goes up to 4.5

- 1751–1759
- 1900–1909
- 1950–1959
- 2010–2017

Swedish females

Fig. 2A) Weights for life expectancy

1751 goes up to 8.

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Fig. 2B) Weights for lifespan inequality

- 1751–1759
- 1900–1909
- 1950–1959
- 2010–2017

1751 goes up to 0.4Å

1900 goes up to 0.3
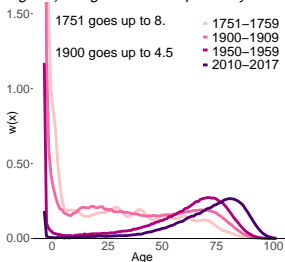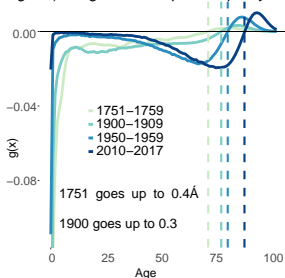
Aburto et al, PNAS (2020)

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Fig. 2A) Weights for life expectancy

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w(x) — Age

Fig. 2B) Weights for lifespan inequality

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g(x) — Age
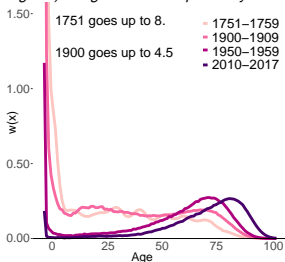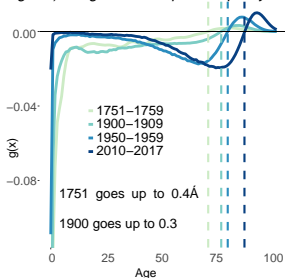
Aburto et al, PNAS (2020)

Other trajectories

Lifespan inequality ($\log(H)$) — Life expectancy (e_o)

Constant change over age

Observed points

Youngest equality

1773 1751 1850 1900 1950 2017
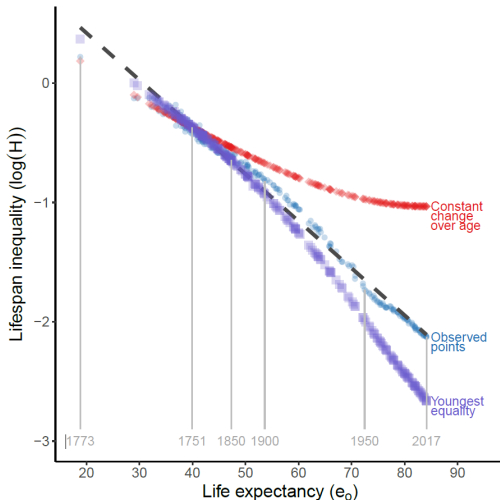
New developments

- ▶ **Sensitivity of lifespan inequality** (van Raalte, Caswell, Wagner and Wrycza)

- ▶ **Specific decompositions of lifespan inequality** (Nau & Firebaugh, Alvarez, Aburto et al, Shkolnikov et al., Fernandez & Beltran-Sanchez)
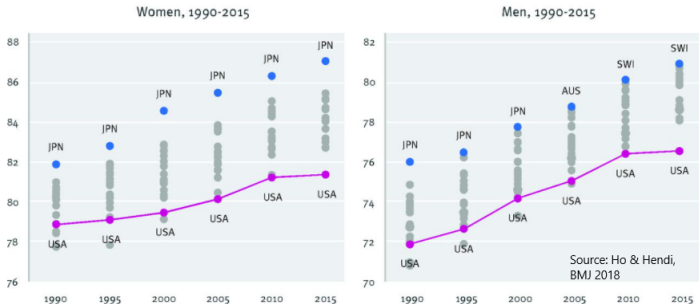
- ▶ **Threshold age** (Gillespie et al, Zhang & Vaupel, Aburto)

- ▶ **General decompositions** (Horiuchi et al, Andreev et al, Caswell)

Recent stalls in life expectancy and increase in lifespan inequality

Disadvantaged groups in Denmark, USA, Scotland, Spain, Finland. At the national level in USA and UK.

Source: Ho & Hendi, BMJ 2018

Recent stalls in life expectancy and increase in lifespan inequality

Disadvantaged groups in Denmark, USA, Scotland, Spain, Finland. At the national level in USA and UK.
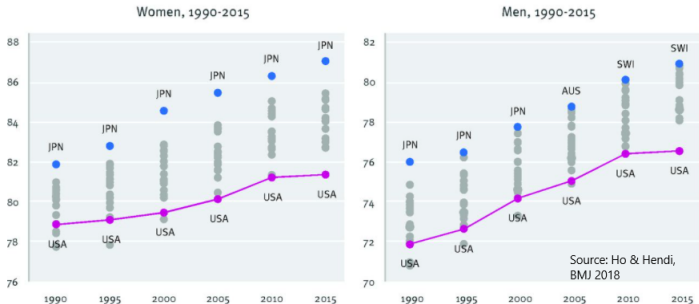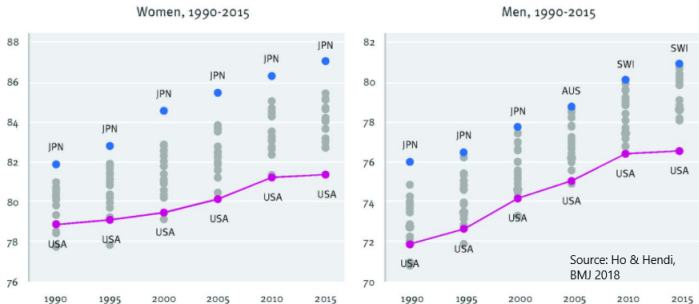

The importance of midlife mortality

Recent stalls in life expectancy and increase in lifespan inequality

Disadvantaged groups in Denmark, USA, Scotland, Spain, Finland. At the national level in USA and UK.

Women, 1990-2015 | Men, 1990-2015

Source: Ho & Hendi, BMJ 2018

The importance of midlife mortality

Focus on developed countries

Last part: Awareness of violence as source of lifespan inequality

Ongoing and future research

Credit: Pixabay

Violence and lifespan inequality

▶ Greater **uncertainty** in the timing of death.

Violence and lifespan inequality

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▶ Implications on **planning** of life's events.

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▶ **Increasing** vulnerability at the societal level.

Violence and lifespan inequality

▶ Greater **uncertainty** in the timing of death.

▶ Implications on **planning** of life's events.

▶ **Increasing** vulnerability at the societal level.

▶ **Ineffectiveness** of policies aiming to protect individuals.

1. How does lifespan inequality **manifest itself** in more violent countries?
2. How does it **compare** with peaceful nations?
3. How does this relationship compare between **men and women**?
4. What **ages explain** difference between violent and peaceful countries?
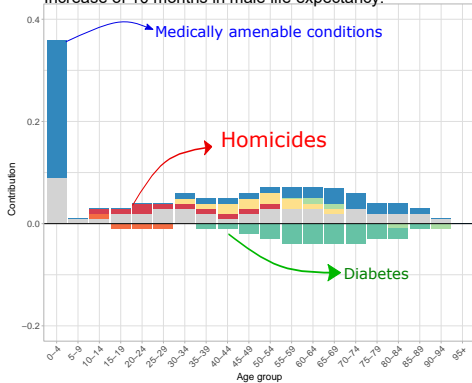
In Mexico: homicides declined in 2000-2005

2000–2005
Increase of 10 months in male life expectancy.
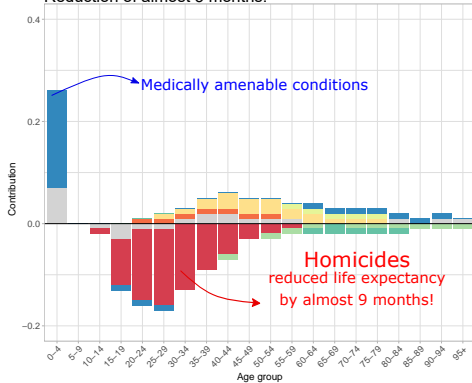
In Mexico: homicides declined in 2000-2005

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Medically amenable conditions

Homicides

Diabetes
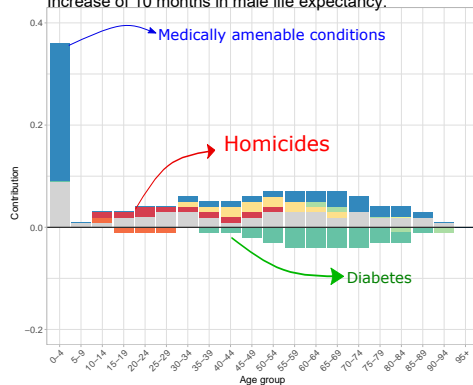
2005–2010
Reduction of almost 3 months.
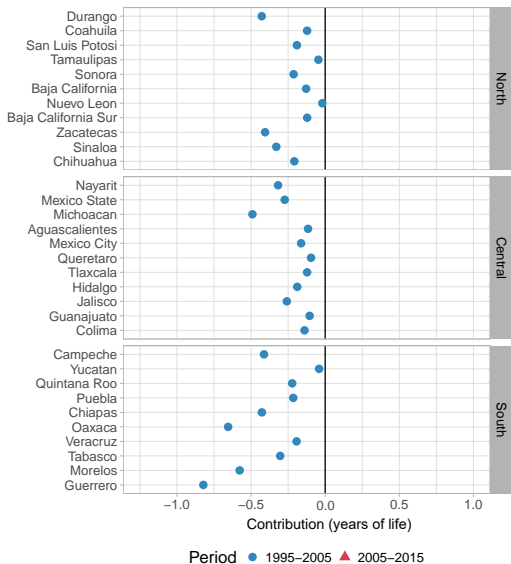
Medically amenable conditions

Homicides
reduced life expectancy
by almost 9 months!

In 2005-2010 rates more than doubled
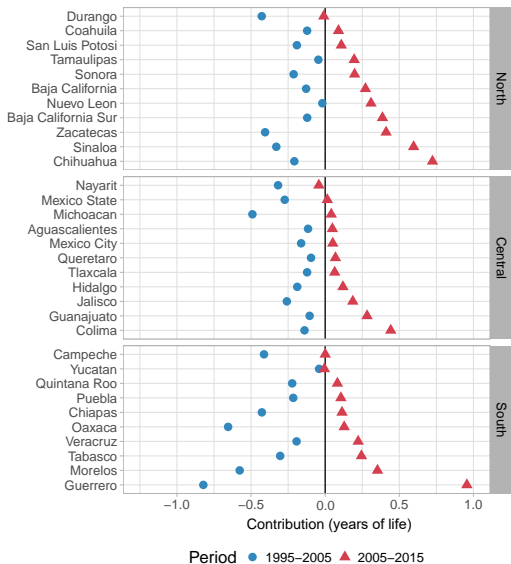(9.5 ⟶ 22 per 100,000 population).

Aburto et al 2016 Health Affairs

Homicide contribution to 👤 Mexican lifespan variation
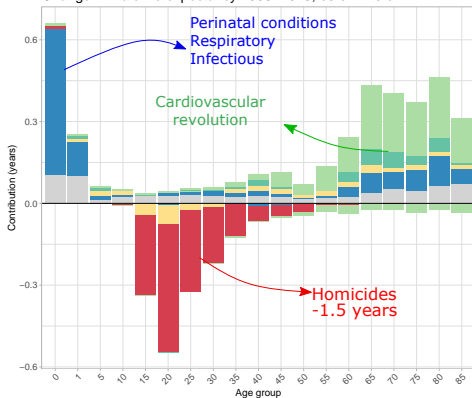

(Aburto & Beltrán-Sánchez 2019 AJPH)

Homicide contribution to 👤 Mexican lifespan variation

Period ● 1995–2005 ▲ 2005–2015

(Aburto & Beltrán-Sánchez 2019 AJPH)

Similar results for Venezuela

Change in male life expectancy 1996–2013, 68.6 to 70.6

Perinatal conditions
Respiratory
Infectious

Cardiovascular
revolution

Homicides
-1.5 years

Change in male lifespan inequality (standard deviation) 1996–2013

Homicides
1.2 years

Lifespan inequality
1996 = 20.7
2013 = 21.6
Change= +0.9
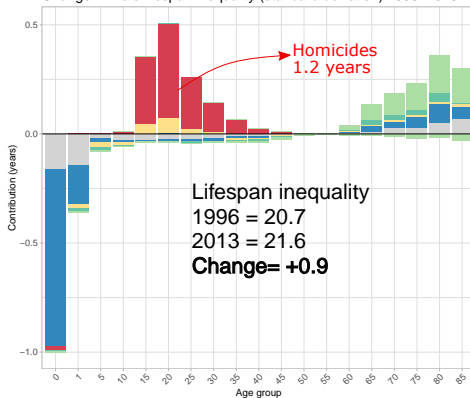
García & Aburto 2019. International Journal of Epidemiology

Global Violence (Internal Peace) and Lifespan Inequality

Men at age 10, year 2017

Dark violet = high level of violence and high lifetime uncertainty

Bright violet = low level of violence and low lifetime uncertainty

Bright blue = high level of violence and low lifetime uncertainty

Bright red = low level of violence and high lifetime uncertainty

Level of Violence →
Lifetime Uncertainty →
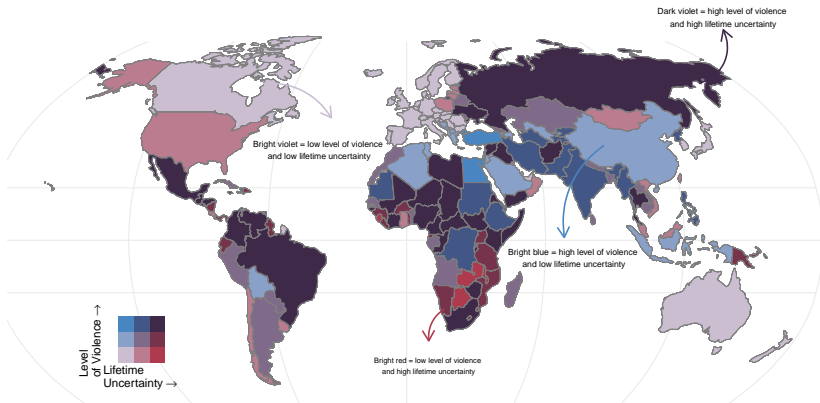
Source: Own elaboration based on Institute for Health Metrics and Evaluation (IHME).
Findings from the Global Burden of Disease Study 2017. Seattle, WA: IHME, 2018;
Institute for Economics & Peace. Global Peace Index 2017: Measuring Peace in a Complex World, Sydney, June 2017

Aburto et al (Working progress)

Aburto et al (Working progress)

From Ronald Lee's *Demography abandons its core*: "A key staff memeber at NICHD recently said "Formal demography is in a coma. Perhaps we should just let it die a natural death"

Where is formal demography going 20 years later?

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