Gains in healthy life expectancy and healthy lifespan variation in past 25 years (1995 to 2020) among men and women of India

Introduction

Population health is frequently assessed using average mortality measures, such as life expectancy, which tend to mask considerable variability in individual lifespans. To better capture this variability, life-span variation has been proposed as a complementary metric to average longevity in evaluating population health dynamics (Edwards & Tuljapurkar, 2005). Traditionally, life expectancy and life-span variation have demonstrated an inverse relationship (Vaupel, Zhang & Raalte, 2011; Colchero et al., 2016), yet emerging evidence indicates a reversal of this trend in certain populations, where a positive correlation is now observed.

To enhance the understanding of population health, the concept of "healthy lifespan inequality" (HLI) offers a more nuanced perspective by focusing on the distribution of healthy years among individuals, as opposed to solely considering overall lifespan. This concept allows for the examination of how populations experience health and disease, providing insights beyond average health measures by illuminating the variability in health states across a population. HLI serves as a critical indicator in health research as it reflects the heterogeneity in population health, bearing implications at both individual and societal levels. Higher HLI values indicate greater inequality in health outcomes, which can influence personal decision-making, particularly in planning for the onset of disease or disability. On a macro scale, HLI offers a meaningful measure of population health by concentrating on "years spent in good health," contrasting traditional metrics that might include periods of illness. Therefore, incorporating HLI alongside conventional mortality and morbidity indicators could provide a more comprehensive understanding of population health disparities and inform more effective policy decisions.

The relationship between lifespan variation, which indicates uncertainty in age at death, and healthy lifespan variation, which reflects uncertainty in age at morbidity onset, can offer insights into whether health gains have been equitable across populations. This also helps in determining whether there is an expansion or compression of morbidity.

Methods

Data Sources

We utilized abridged life table information from the Sample Registration System (SRS) for the years 1991 to 2020. These life tables provide detailed columns for age groups: 0-1 years, 1-5 years, 5-10 years, and so on, up to 85+ years in five-year intervals. Estimates are available for both genders, across rural and urban areas, and for all Indian states and at the national level.

Additionally, morbidity data from the Global Burden of Disease (GBD) study, including mortality rates, prevalence rates of various diseases, years lived with disability (YLD), years of life lost (YLL), disability-adjusted life years (DALY), and healthy life expectancy (HALE), was used. These estimates are available for both genders and the same age groups as those in the SRS data.

Statistical Analysis

We computed the life expectancy estimates from the probability of death (qx) values across the specified age groups from the SRS for all years and both genders. Healthy life expectancy was calculated using the Sullivan method, which incorporates years of life lost due to disability (a product of disease prevalence and associated disability weights).

Lifespan variation and healthy lifespan variation were measured using the Gini coefficient and the coefficient of variation:

Gini coefficient was calculated as follows:

$$G_x = 1 - \frac{1}{e_x l_x}\int_x^{\infty}[l(t)]^2\,dt \cong 1 - \frac{1}{e_x l_x}\sum_{t=x}^{\omega-1}[(l_{t+1})^2 + a_x((l_t)^2 - (l_{t+1})^2)]$$

Coefficient of variation was calculated as:

$$STD_x = \sqrt{\frac{\sum_{y=x}^{\omega} d_y(\bar{y}_y)^2}{l_x} - (x+e_x)^2}$$

$$CoefVar_x = \frac{STD_x}{x+e_x}$$

Where the notations follow the standard life table notations

Results

Our analysis revealed that the relationship between life expectancy and lifespan inequality, as well as healthy lifespan inequality and healthy life expectancy, holds for India as well. Over the past 25 years, increases in life expectancy and healthy life expectancy in India for both genders have been accompanied by a decline in lifespan and healthy lifespan variation.

Key findings include:

a) Life expectancy and Healthy Life Expectancy

1. Life expectancy and healthy life expectancy are consistently higher for females across all ages and years (1995-2020).
2. While females experienced higher absolute gains in both life expectancy and healthy life expectancy, the percentage gain in healthy life expectancy relative to life expectancy was greater for males.
3. Gains in both life expectancy and healthy life expectancy diminish with age, yet this trend is consistent across genders.

b) Life Expectancy and Lifespan Variation

1. Lifespan variation, measured by both the Gini coefficient and the coefficient of variation, has decreased more for females.
2. Lifespan variation increases sharply between ages 40 and 45, doubling for men and increasing by 70% for women. A similar trend is observed between ages 66 and 70 for both genders.
3. From 1995 to 2020, lifespan inequality at ages 40-45 and 65-70 showed a substantial decline, especially among females.
4. While the coefficient of variation for males showed larger gains at age 0, females demonstrated higher gains at ages 40-45 and 65-70. At ages 15-20, no significant gender differences were observed.
5. In 1995, lifespan variation across age groups increased for females but substantially declined by 2020.

c) Healthy Life Expectancy and Healthy Lifespan Variation

1. Healthy life expectancy has decreased for both genders at age 0, while healthy lifespan variation showed minimal changes between 1995 and 2020.
2. By 2021, healthy lifespan variation was relatively stable across ages and genders, with a slight decline with increasing age.
3. In 1995, healthy lifespan variation remained stable with age for males but increased for females.

d) Lifespan Inequality and Healthy Lifespan Inequality

1. In 1995, lifespan inequality and healthy lifespan inequality were similar, though the latter was slightly higher. By 2021, lifespan inequality had declined substantially, while healthy lifespan inequality showed a smaller reduction.
2. In 1995, the difference in lifespan inequality and healthy lifespan inequality was greater for men, but by 2020, this gap had converged for both genders.

Interpretation

These results suggest that while life expectancy has improved with a significant reduction in lifespan variation, indicating the convergence of ages at death (rectangularization of mortality), morbidity remains varied, with a wide range of ages at morbidity onset. Females have shown greater gains in both life expectancy and lifespan variation than males, with smaller increases in lifespan variation across the years. In contrast, the onset of morbidity shows wide variation, especially at younger and older ages.

Further analyses will explore:

1. Whether morbidity is truly compressing or expanding across India and its states.
2. The geographic variation in age at death and morbidity onset by gender.
3. Patterns of reduction in healthy lifespan variation and lifespan variation across Indian states.

This analysis will enhance our understanding of population health in India and provide valuable insights for health policy.

Table1: Life expectancy, Healthy life expectancy, Lifespan variation, Healthy lifespan variation at the ages 0, 15, 40, and 65 in India.

Variables	Male		Female	
	1991-95	2016-20	1991-95	2016-20
Age 0-1				
Life expectancy	59.3	68.3	60.3	71.1
Healthy life expectancy	51.9	60.0	50.8	60.3
Lifespan variation Gini coefficient(AID)	0.36 (21.6)	0.17 (11.7)	0.41 (25.2)	0.17 (12.6)
Lifespan variation (Coefficient of variation)	0.023	0.013	0.018	0.013
Healthy lifespan variation Gini coefficient (AID)	0.96 (57.0)	0.95 (65.4)	0.95 (57.3)	0.95 (67.6)
Healthy lifespan variation (Coefficient of variation)	0.028	0.02	0.024	0.02
Age 15-19				
Life expectancy	52.4	56.3	54.5	59.5
Healthy life expectancy	45.0	48.5	44.6	49.1
Lifespan variation Gini coefficient(AID)	0.36 (18.9)	0.17 (9.6)	0.42 (23.1)	0.17 (10.3)
Lifespan variation (Coefficient of variation)	0.02	0.008	0.024	0.008
Healthy lifespan variation Gini coefficient (AID)	0.94 (49.7)	0.94 (53.4)	0.93 (50.9)	0.93 (55.8)
Healthy lifespan variation (Coefficient of variation)	0.027	0.018	0.028	0.018
Age 40-45				
Life expectancy	30.1	33.1	32.7	35.8
Healthy life expectancy	24.5	27.1	25.4	28.1
Lifespan variation Gini coefficient(AID)	0.62 (18.8)	0.25 (8.5)	0.71 (23.3)	0.26 (9.5)
Lifespan variation (Coefficient of variation)	0.021	0.007	0.034	0.007
Healthy lifespan variation Gini coefficient (AID)	0.92 (27.7)	0.91 (30.4)	0.90 (29.5)	0.91 (32.3)
Healthy lifespan variation (Coefficient of variation)	0.027	0.016	0.036	0.016
Age 65-70				
Life expectancy	11.9	13.8	12.9	15.1
Healthy life expectancy	6.8	10.4	9.2	11.1
Lifespan variation Gini coefficient(AID)	4.7 (44.3)	0.52 (7.2)	2.5 (33.3)	0.58 (8.8)
Lifespan variation (Coefficient of variation)	0.025	0.007	0.045	0.007
Healthy lifespan variation Gini coefficient (AID)	0.81 (9.7)	0.77 (10.7)	0.83 (10.8)	0.80 (12.2)
Healthy lifespan variation (Coefficient of variation)	0.031	0.014	0.045	0.014