Trends in Gain in Life Expectancy at Birth Following the Elimination of Specific Diseases in India and Its Selected States (2003-2021)

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ABSTRACT

Background: Life table is an important demographic technique used in analysis of mortality and other demographic processes. Life expectancy, a statistical measure to portray average life span a person is expected to live at a given age under given age-specific mortality rates, is generated from life tables. Cause-deleted life table measures gain in life expectancy after elimination of a specific disease. Changes in life expectancy over time serve as an interesting public health indicator for medical, social and economic developments within populations. The present study estimates the gain in life expectancy and effect of ten leading causes of death on overall mortality experience of India and its selected states for the years 2003, 2009, 2015 and 2021 by using MCCD data.

Material and Methods: Based on data on causes of death for the years 2003, 2009, 2015 and 2021, abridged life tables, multiple decrement and cause eliminated life tables were carried out separately by sex and age groups for India and its selected states for life expectancy estimates. By eliminating certain causes of death, a more accurate life expectancy capable of predicting gender difference in life expectancy is obtained.

Results: The results show that in India and its selected states, circulatory diseases remain a primary target for improving life expectancy. Their increasing contribution to gain in life expectancy suggests either rising mortality from these diseases or slower progress in their control compared to other causes.

Conclusion: The study examined how each of the ten diseases influences the life expectancy of the Indian population. The greater the increase in life expectancy following the elimination of a specific cause of death, the larger the disease's impact on overall longevity. These findings provide valuable evidence for the government to strengthen public health policies and strategies aimed at reducing preventable mortality and improving population health.

Keywords: Life expectancy, gain, life table, mortality, elimination, circulatory system, MCCD

INTRODUCTION

Life expectancy is a statistical measure of average life span a person is expected to live at a given age under given age specific mortality rates[1]. It is a representative and comprehensive indicator to judge social and economic status and quality of life of a country or region[2]. Life expectancy at birth is used as a convenient summary measure of mortality of a population. It is easy to interpret in terms of expectation of life[3].

In India, over the last century, life expectancy has increased by almost threefold, rising from 23 years in 1901 to

72.9 years in 2018-22[4,5]. However, India does not have good quality data on health situation of its population particularly the rural population where three-fourth of its total population lives. Of course, there is Medical Certification of Cause of Death (MCCD) scheme for obtaining authentic and scientific information regarding causes of mortality which is limited to urban population only[6].

The elimination of a specific cause of death means that on an average population will live more than they would in the presence of that disease. It represents the added years of life expectancy the population would receive if the death from a particular cause was reduced or eliminated as a competing risk of death[7-11]. It explains the impact of a certain disease on life expectancy and is not affected by the age structure of the population, facilitating comparisons between diseases[12].

The gain in life expectancy is one of the indicators explaining the effectiveness of health care system[13]. Total elimination of a certain cause of death leads to the maximal number of years to which the life expectancy could be prolonged.

The present study aims to estimate the trends in gain in life expectancy at birth after elimination of ten leading causes of deaths viz, certain infectious and parasitic diseases (A00-B99); neoplasms (C00-D48); endocrine, nutritional and metabolic diseases (E00-E89); diseases of the circulatory system (I00-I99); diseases of the respiratory system (J00-J98); diseases of the digestive system (K00-K92); diseases of the genitourinary system (N00-N99); certain conditions originating in the perinatal period (P00-P96); congenital malformations, deformations and chromosomal abnormalities Q00-Q99); and injury, poisoning and certain other consequences of external causes (S00-T98) in India and its selected states viz., Bihar, Kerala, Maharashtra, Rajasthan and Tamil Nadu during the period from 2003 to 2021.

MATERIAL & METHODS

The secondary data for the study has been taken from Medical Certification of Cause of Death (MCCD) reports for the years 2003[14], 2009[15], 2015[16], and 2021[17]. The MCCD under Civil Registration System covers mostly those deaths, which occur in medical institutions located in urban areas. It has been operational in the country but with varying levels of efficiency across the States/Union Territories. The percentage of medically certified deaths to total registered deaths during 2003, 2009, 2015 and 2021 was 13.5%, 19.9%, 22% and 23.4% respectively[14-17].

Data derived from MCCD is tabulated in conformity with the International Classification of Diseases (ICD) - Tenth Revision (1993)[18]. The underlying cause of death is taken into account while tabulating the cause-specific mortality[19]. The MCCD data was collected according to ICD-9 classification from 1990 to 1998 and ICD-10 classification from 1999 to 2021. Detailed information is available elsewhere[20-22].

In 2003, India recorded a total of 43,55,607 registered deaths, of which 5,86,700 (or 13.5%) were medically certified. Among these medically certified deaths, the distribution across its selected states was as follows: Bihar reported 5,767 deaths (1%), Kerala 15,883 deaths (2.7%), Maharashtra 1,82,910 deaths (31.2%), Rajasthan 26,408 deaths (4.5%), and Tamil Nadu 85,174 deaths (14.5%)[14].

In 2009, India recorded a total of 47,55,054 registered deaths, of which 9,46,018 (or 19.9%) were medically certified. Among these medically certified deaths, the distribution across its selected states was as follows: Bihar reported 15,415 deaths (11.2%), Kerala 25,599 deaths (11%), Maharashtra 2,12,335 deaths (33.5%), Rajasthan 32,196 deaths (9.5%), and Tamil Nadu 1,46,461 deaths (32.7%)[15].

In 2015, India recorded a total of 53,74,824 registered deaths, of which 11,83,052 (or 22%) were medically certified. Among these medically certified deaths, the distribution across its selected states was as follows: Bihar reported 13,443 deaths (6.6%), Kerala 32,416 deaths (12.8%), Maharashtra 2,32,259 deaths (34.5%), Rajasthan 51,260

deaths (12.5%), and Tamil Nadu 2,30,189 deaths (40.5%)[16].

In 2021, India recorded a total of 1,02,24,506 registered deaths, of which 23,95,128 (or 23.4%) were medically certified. Among these medically certified deaths, the distribution across its selected states was as follows: Bihar reported 23,556 deaths (4.5%), Kerala 35,965 deaths (10.6%), Maharashtra 3,94,610 deaths (39.1%), Rajasthan 1,07,715 deaths (22.6%), and Tamil Nadu 4,45,577 deaths (50.9%)[17].

In the MCCD reports, a significant number of cases lacked information on the age at death. To address this, the study redistributed the deaths recorded under "age not stated" proportionally across all age groups, based on the distribution of known deaths in those age groups. These adjusted figures were then used to estimate age-sex-specific death rates, which served as the basis for constructing life tables.

The study used the average number of deaths over a three-year period (2019–2021) for all leading causes of death. This approach helps smooth out annual fluctuations and provides more reliable and representative estimates of life expectancy[17,23,24]. To construct life tables and estimate life expectancy, age-specific death rates were calculated by dividing the three-year average deaths by the mid-year population of 2020[25]. These calculations were performed separately for males and females across different age groups. The resulting age-specific death rates formed the basis for estimating life expectancy at birth. Given the inclusion of the COVID-19 period, using the 2019–2021 average also captures the impact of the pandemic on mortality, offering insights into how COVID-19 influenced overall death rates during this time.

Statistical Analysis

The gain in life expectancies was calculated according to the following steps:

First, conventional abridged life tables were constructed using age-specific death rates. Life tables are commonly used to analyze the mortality patterns of a given cohort. The life expectancy at birth represents the average number of years a person is expected to live under current mortality conditions. Similarly, life expectancy at specific ages indicates the average number of remaining years a person can expect to live upon reaching that age.

The values of $_nq_x$ (the probability of death between age x and x+n) were calculated by using the relation between the probability of death ($_nq_x$) and the observed age specific death rates ($_nm_x$) by Greville formula[26]:

$$_nq_x = \frac{_nm_x}{\frac{1}{n} + _nm_x[\frac{1}{2} + \frac{n}{12}(_nm_x - \log_e c)]}$$

where, $\log_e c = 0.09$.

Secondly, multiple decrement life tables were constructed using the values of $_nd_x$ and $_nq_x$ obtained from the abridged life tables. In these tables, the number or proportion of individuals dying at each age is further classified by specific causes of death, represented as $_nd_{x,j}$ and $_nq{x,j}$. Multiple decrement life tables follow similar principles as those used in the construction of abridged life tables but account for the possibility of different causes of death (decrements). This is achieved by allocating deaths across causes based on the cause-specific mortality ratio, calculated as $_nD_{x,j}/_nD_x$.

Finally, cause-eliminated life tables were constructed by creating a life table that excludes mortality from a specific cause of death. The construction process follows the same approach as that used for the abridged life table, with one key difference: the probability of dying $_nq_x$ is adjusted to exclude the selected cause. This adjusted probability, denoted as $_nq_{x,-j}$, is calculated using the following equation:

$_nq_{x,-j} = 1 - _nP_{x,-j}$ if we then substitute $_nP_{x,-j} = _nP_x (1 - _nD_{x,j}/_nD_x)$, we get

$_nq_{x,-j} = 1 - _nP_x (1 - _nD_{x,j}/_nD_x)$

This method allows for the estimation of survival probabilities after eliminating a specific cause of death. Here, $_nP_{x,-j}$ represents the probability of surviving from age x to x+n

after removing cause j. $_nP_x$ is the original survival probability over the same age interval from the abridged life table, calculated as 1- $_nq_x$. $_nD_{x,j}$ refers to the number of deaths due to cause j, and $_nD_x$ is the total number of deaths between ages x to x+n.

Life expectancy at various ages was then calculated under the hypothetical scenario where a specific cause of death is eliminated. The gain in life expectancy is determined by the difference between life expectancy values from the multiple decrement life table and the corresponding cause-eliminated life table. All life tables were constructed using Microsoft Excel.

RESULTS

The author constructed abridged life tables for the period under report based on the mortality rates of all causes of deaths by sex and are given in Table 1. The SRS based abridged life tables are also used for comparison. It may be seen that there is an increase in the life expectancy at birth of males and females over the years under report.

The result shows absolute and relative changes in life expectancy at birth (age 0) and at age 70+ in India and its selected states for the period from 2003 to 2021.

India:
- **2003-2009:** Life expectancy at age 0 increased slightly, with males seeing a 1-year increase and females a 1.4-year increase. However, life expectancy at age 70+ showed slight declines for both males and females.
- **2009-2015:** Life expectancy at age 0 improved moderately, especially for males (2.5 years). However, life expectancy at age 70+ showed a slight decline.
- **2015-2021:** Life expectancy at age 0 showed moderate growth (1 year for males, 1.3 years for females), and life

expectancy at age 70+ grew notably, especially for females.

Bihar:
- **2003-2009:** Life expectancy at age 0 showed a small increase for males and females, but for older age groups (70+), there were significant increases, particularly for females, with a 24.6% relative change.
- **2009-2015:** Life expectancy at age 0 increased significantly, especially for males (9.4%), while at age 70+, a large decrease for females, and a positive change for males.
- **2015-2021:** Life expectancy at age 0 decreased for both males and females, and life expectancy at age 70+ dropped considerably.

Kerala:
- **2003-2009:** It showed steady improvements at both age 0 and age 70+ for both genders. The relative change at age 70+ was relatively high (8.9% for males, 5.2% for females).
- **2009-2015:** Life expectancy at age 0 showed a minor increase, but life expectancy at age 70+ showed mixed results, with males having a slight decline and females showing an increase.
- **2015-2021:** Life expectancy at age 0 decreased for both genders, but life expectancy at age 70+ showed small positive changes for males.

Maharashtra:
- **2003-2009:** For males, life expectancy at age 0 showed a strong improvement, but life expectancy at age 70+ saw a large decline for both genders, with males seeing a -15.8% relative change.
- **2009-2015:** Life expectancy at age 0 increased, while life expectancy at age 70+ showed a decline, for both genders.
- **2015-2021:** Life expectancy at age 0 showed moderate improvements, and life expectancy at age 70+ also showed significant growth, particularly for males.

Table 1: Life expectancy at birth by sex from SRS urban abridged life tables and abridged life tables constructed from MCCD data (2003-2021)

	SRS*								MCCD							
	2003 (2003-07)		2009 (2009-13)		2015 (2015-19)		2021 (2018-22)		2003		2009		2015		2021	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
India	67.5	70.7	69.6	73	71.8	74.2	71.3	74.7	69.0	72.7	70.0	74.1	72.4	75.3	73.4	77.3
Bihar	68	67.2	69.2	71.2	72.5	71.4	71.3	71.5	68.2	70.1	68.3	76.4	75.4	73.6	73.5	72.8
Kerala	71.4	76.7	72.7	77.4	72.1	78	71.1	77.4	71.8	77.5	73.2	78.4	73.4	79.8	70.5	80.1
Maharashtra	68.7	72.5	71.6	74.8	73.2	76	73.2	76.6	69.5	73.3	71.5	77.1	73.3	78.7	74.6	79.2
Rajasthan	66.2	69.8	68.3	71.9	71.8	73.3	70.4	74.8	65.9	69.4	67.6	74.4	71.7	74.3	70.9	77.5
Tamil Nadu	68.4	72.1	70.1	74.1	73	77.1	74.3	78.3	69.1	74.1	70.7	75.5	72.1	76.4	79.8	85.9

M = Male; F = Female

*5,27-29

Absolute and relative change in life expectancy in India and its selected states during 2003-2021 and sex difference during that period at age 0 and age 70+ are given in tables 2-3.

Table 2: Absolute and relative change in life expectancy (2003-2021)

		Change in Life Expectancy							
		At age 0				At age 70+			
		Male		Female		Male		Female	
		Years	%	Years	%	Years	%	Years	%
2003-2009	India	1.0	1.4	1.4	1.9	-0.1	-0.7	-1.0	-6.7
	Bihar	0.1	0.1	6.3	8.3	0.6	4.7	5.1	24.6
	Kerala	1.4	2.0	1.0	1.2	1.1	8.9	0.8	5.2
	Maharashtra	2.1	2.9	3.9	5.0	-2.3	-15.8	-1.8	-10.7
	Rajasthan	1.7	2.5	5.1	6.8	-1.3	-11.7	-1.5	-9.1
	Tamil Nadu	1.6	2.3	1.3	1.8	-0.9	-6.9	-3.1	-20.0
2009-2015	India	2.5	3.4	1.2	1.5	-0.5	-3.7	-0.3	-2.0
	Bihar	7.1	9.4	-2.8	-3.9	4.6	26.4	-6.1	-41.8
	Kerala	0.2	0.2	1.4	1.8	-0.4	-3.3	1.2	7.3
	Maharashtra	1.7	2.4	1.6	2.1	-1.8	-14.1	-0.5	-3.1
	Rajasthan	4.1	5.7	-0.1	-0.1	2.7	19.6	-2.2	-15.5
	Tamil Nadu	1.4	2.0	1.0	1.3	0.4	3.0	-0.4	-2.6
2015-2021	India	1.0	1.3	2.0	2.6	1.6	10.6	2.1	12.5
	Bihar	-1.9	-2.6	-0.8	-1.1	-4.3	-32.8	-1.4	-10.6
	Kerala	-2.9	-4.2	0.2	0.3	0.1	0.8	-0.5	-3.1
	Maharashtra	1.3	1.7	0.5	0.6	2.1	14.1	1.3	7.4
	Rajasthan	-0.8	-1.1	3.1	4.0	-0.4	-3.0	5.6	28.3
	Tamil Nadu	7.6	9.6	9.5	11.0	7.5	35.9	8.5	36.0

Rajasthan:
- **2003-2009:** Life expectancy at age 0 showed a steady increase, life expectancy at age 70+ dropped significantly, for both genders.
- **2009-2015:** Life expectancy at age 0 and at age 70+ improved for males and declined for females.
- **2015-2021:** Life expectancy at age 0 and at age 70+ improved for females and declined for males.

Tamil Nadu:
- **2003-2009:** Life expectancy at age 0 increased moderately for both genders, but there was a considerable drop in life expectancy at age 70+, particularly for females, with a 20% relative change.
- **2009-2015:** Life expectancy at age and at age 70+ showed a moderate improvement in both genders. However, there was a decline in females at age 70+.

- **2015-2021:** Life expectancy at age 0 and at age 70+ saw a larger increase for both genders.

Males generally experienced higher increases in life expectancy at age 0 compared to females across most states. Older populations (age 70+) showed more variability, with some states (like Bihar and Maharashtra) experiencing significant declines in life expectancy for older individuals, especially in earlier periods. Bihar experienced large fluctuations in both male and female life expectancy, with notable increases in the earlier periods and sharp declines later. Kerala showed relatively stable improvements at both age 0 and age 70+. Tamil Nadu showed the most consistent and significant improvements, especially in the last period (2015-2021), with life expectancy at age 70+ rising dramatically, for both genders.

Table 3: Absolute and relative difference in life expectancy between sexes at different ages (2003-2021)

		Sex difference			
		At age 0		At age 70+	
		Years	M/F (%)	Years	M/F (%)
2003	India	3.7	94.9	1.9	88.1
	Bihar	1.9	97.2	3.4	78.2
	Kerala	5.7	92.6	3.2	77.9
	Maharashtra	3.8	94.8	1.7	90.9
	Rajasthan	3.5	94.9	5.5	69.3
	Tamil Nadu	5.1	93.2	4.7	74.7
2009	India	4.1	94.4	1.0	93.3
	Bihar	8.2	89.3	7.9	61.8
	Kerala	5.2	93.3	2.9	81.0
	Maharashtra	5.6	92.8	2.2	86.9
	Rajasthan	6.9	90.8	5.3	67.7
	Tamil Nadu	4.8	93.7	2.5	83.9
2015	India	2.8	96.3	1.2	91.8
	Bihar	-1.8	102.4	-2.8	119.2
	Kerala	6.4	91.9	4.5	72.7
	Maharashtra	5.5	93.0	3.5	78.5
	Rajasthan	2.6	96.4	0.4	97.2
	Tamil Nadu	4.3	94.4	1.7	88.7
2021	India	3.8	95.0	1.7	89.9
	Bihar	-0.7	100.9	0.1	99.2
	Kerala	9.6	88.0	3.9	75.6
	Maharashtra	4.7	94.1	2.7	84.7
	Rajasthan	6.6	91.5	6.4	67.7
	Tamil Nadu	6.2	92.8	2.7	88.6

The result shows sex differences in life expectancy (absolute and relative) at birth (age 0) and age 70+ for India and its selected states between 2003 and 2021.

Absolute difference (years): Female life expectancy – Male life expectancy (in years). Positive → females live longer. Negative → males live longer.

Relative difference (M/F %): (Male life expectancy/Female life expectancy) ×100. A lower % means a larger female advantage; values above 100 mean male advantage.

India:
• Female advantage in life expectancy persisted across years.
• Slight fluctuations but no reversal.
• The gender gap at birth is larger than at age 70+, meaning differences narrow with age.

Bihar:
• 2003–2009: Sharp *increase* in female advantage (1.9 → 8.2 years at birth).
• 2015: Male advantage appears (–1.8 years at birth, M/F 102.4%).
• 2021: Almost parity (–0.7 years).
Bihar shows the most volatility, with years where men outlive women.

Kerala:
• Highest female advantage throughout.
• At birth: 5.7 → 9.6 years (2003–2021).
• At 70+: 3.2 → 3.9 years.
Kerala consistently leads in gender longevity advantage.

Maharashtra:
• Steady female advantage.

• At birth: 3.8 → 4.7 years.
• At 70+: moderate (1.7 → 2.7 years).
Stable, moderate female advantage.

Rajasthan:
• 2003–2021: Female advantage grows strongly (3.5 → 6.6 years at birth).
• Elderly gap also widens (5.5 → 6.4 years).
Persistent and increasing female advantage.

Tamil Nadu:
• Consistent female advantage.
• At birth: 5.1 → 6.2 years.
• At 70+: fluctuates (4.7 → 2.7 years).
Strong early-life advantage, narrowing at older ages.

Kerala has the largest female advantage (nearly 10 years). Bihar shows male advantage or parity. Rajasthan and Tamil Nadu also display large gaps favoring females. Female advantage persists nationally, except for temporary reversals in Bihar. Regional variation is large — from 0 in Bihar to 10 years in Kerala. Relative gaps (M/F %) show decreasing values (toward 90%) where female advantage is strong. Gender differences shrink with age (age 70+ gaps smaller than at birth), possibly due to selective survival.

Trend of life expectancy at birth during 2003-2021

Table 4: Trend in life expectancy at birth by sex after elimination of a specific cause of death in India (2003-2021)

	Male				Female			
	2003	2009	2015	2021	2003	2009	2015	2021
All Causes	69.0	70.0	72.4	73.4	72.7	74.1	75.3	77.3
I	71.6	72.5	74.3	74.7	75.1	76.4	77.0	78.5
II	69.7	70.8	73.3	74.1	73.6	75.0	76.2	78.1
IV	69.8	70.9	73.2	74.4	73.7	75.1	76.2	78.5
IX	78.3	80.5	83.4	82.0	84.0	85.9	88.3	87.7
X	71.4	72.1	74.5	75.7	75.6	76.2	77.1	79.5
XI	69.8	70.7	73.2	74.0	73.2	74.5	75.7	77.6
XIV	69.6	70.6	73.0	74.0	73.2	74.7	75.8	77.8
XVI	70.8	71.7	73.8	74.6	75.1	75.9	76.9	78.4
XVII	69.1	70.1	72.6	73.5	72.9	74.2	75.4	77.4
XIX	70.6	71.1	73.4	74.2	73.9	74.9	75.9	77.8

I: Certain infectious and parasitic diseases	II: Neoplasms
IV: Endocrine, nutritional and metabolic diseases	IX: Diseases of the circulatory system
X: Diseases of the respiratory system	XI: Diseases of the digestive system

XIV: Diseases of the genitourinary system	XVI: certain conditions originating in the perinatal period
XVII: Congenital malformations, deformations and chromosomal abnormalities	XIX: Injury, poisoning and certain other consequences of external causes

Table 5: Trend in life expectancy at birth by sex after elimination of a specific cause of death in Bihar (2003-2021)

	Male				Female			
	2003	**2009**	**2015**	**2021**	**2003**	**2009**	**2015**	**2021**
All Causes	68.2	68.3	75.4	73.5	68.2	76.4	73.6	72.8
I	71.0	69.7	78.4	74.7	71.0	77.8	76.2	74.4
II	68.2	68.3	76.0	73.6	68.2	76.4	74.0	72.9
IV	68.4	68.5	76.2	73.6	68.4	76.6	74.4	72.9
IX	78.5	82.9	97.4	81.6	78.5	106.8	89.3	82.0
X	68.7	69.2	76.4	74.2	68.7	77.9	74.6	73.9
XI	68.4	69.4	76.4	73.7	68.4	77.4	74.3	73.1
XIV	68.5	68.6	76.6	76.3	68.5	76.7	74.6	76.0
XVI	70.6	69.9	77.5	73.9	70.6	78.3	76.8	73.4
XVII	68.2	68.3	75.4	73.5	68.2	76.4	73.7	72.8
XIX	70.4	68.8	76.0	73.6	70.4	77.2	74.4	73.2

I: Certain infectious and parasitic diseases	II: Neoplasms
IV: Endocrine, nutritional and metabolic diseases	IX: Diseases of the circulatory system
X: Diseases of the respiratory system	XI: Diseases of the digestive system
XIV: Diseases of the genitourinary system	XVI: certain conditions originating in the perinatal period
XVII: Congenital malformations, deformations and chromosomal abnormalities	XIX: Injury, poisoning and certain other consequences of external causes

Table 6: Trend in life expectancy at birth by sex after elimination of a specific cause of death in Kerala (2003-2021)

	Male				Female			
	2003	**2009**	**2015**	**2021**	**2003**	**2009**	**2015**	**2021**
All Causes	71.8	73.2	73.4	70.5	77.5	78.4	79.8	80.1
I	73.1	74.2	74.3	70.9	78.9	79.3	80.8	80.5
II	74.0	75.5	76.1	72.6	79.8	80.5	82.5	82.0
IV	73.0	74.7	75.0	72.5	78.9	80.1	82.4	83.1
IX	81.1	80.9	80.1	75.3	88.9	89.3	92.4	88.0
X	74.1	75.6	76.0	71.7	80.4	81.2	82.5	81.3
XI	72.6	74.2	74.7	71.5	78.3	79.0	80.6	80.6
XIV	72.5	73.6	74.0	70.9	78.3	78.8	80.5	80.5
XVI	72.2	73.7	73.9	71.2	78.2	79.0	80.4	80.2
XVII	71.8	73.3	73.7	71.0	77.5	78.5	80.2	80.3
XIX	72.7	73.9	74.2	71.1	78.4	79.0	80.3	80.4

I: Certain infectious and parasitic diseases	II: Neoplasms
IV: Endocrine, nutritional and metabolic diseases	IX: Diseases of the circulatory system
X: Diseases of the respiratory system	XI: Diseases of the digestive system
XIV: Diseases of the genitourinary system	XVI: certain conditions originating in the perinatal period
XVII: Congenital malformations, deformations and chromosomal abnormalities	XIX: Injury, poisoning and certain other consequences of external causes

Table 7: Trend in life expectancy at birth by sex after elimination of a specific cause of death in Maharashtra (2003-2021)

	Male				Female			
	2003	**2009**	**2015**	**2021**	**2003**	**2009**	**2015**	**2021**
All Causes	69.5	71.5	73.3	74.6	73.3	77.1	78.7	79.2
I	72.6	75.6	75.3	75.5	76.5	81.2	80.8	80.3

II	70.4	72.5	74.3	75.8	74.2	78.3	80.0	81.1
IV	70.1	72.2	73.9	76.6	74.0	77.9	79.5	82.3
IX	79.5	80.7	83.6	81.5	83.9	87.6	93.5	87.3
X	73.7	74.0	75.5	75.9	78.4	79.9	81.3	81.0
XI	70.4	72.4	73.9	75.3	74.1	77.4	79.1	79.6
XIV	70.1	72.2	73.9	74.9	74.0	77.7	79.5	79.7
XVI	70.7	72.3	73.8	75.1	75.4	78.1	79.5	79.7
XVII	69.9	71.7	73.3	74.7	73.9	77.3	78.8	79.3
XIX	71.7	73.0	74.4	75.3	75.5	78.1	79.2	79.4

I: Certain infectious and parasitic diseases	II: Neoplasms
IV: Endocrine, nutritional and metabolic diseases	IX: Diseases of the circulatory system
X: Diseases of the respiratory system	XI: Diseases of the digestive system
XIV: Diseases of the genitourinary system	XVI: certain conditions originating in the perinatal period
XVII: Congenital malformations, deformations and chromosomal abnormalities	XIX: Injury, poisoning and certain other consequences of external causes

Table 8: Trend in life expectancy at birth by sex after elimination of a specific cause of death in Rajasthan (2003-2021)

	Male				Female			
	2003	2009	2015	2021	2003	2009	2015	2021
All Causes	65.9	67.6	71.7	70.9	69.4	74.4	74.3	77.5
I	69.2	70.8	75.0	72.3	74.0	77.8	77.4	79.0
II	66.4	68.1	72.3	71.3	70.1	75.0	74.9	78.0
IV	66.3	68.4	72.2	71.2	70.0	75.7	75.1	78.1
IX	73.5	75.7	79.2	75.6	79.9	89.5	84.3	85.1
X	68.0	70.8	76.2	77.3	72.3	77.2	77.4	85.4
XI	66.8	68.2	72.4	71.5	70.6	74.7	74.8	77.9
XIV	66.5	67.8	72.3	71.3	70.3	74.8	75.0	77.9
XVI	68.5	69.9	74.3	72.8	71.6	77.9	77.0	79.1
XVII	65.9	67.6	71.8	71.0	69.4	74.5	74.4	77.5
XIX	68.5	67.6	72.9	71.7	73.2	74.4	75.3	78.1

I: Certain infectious and parasitic diseases	II: Neoplasms
IV: Endocrine, nutritional and metabolic diseases	IX: Diseases of the circulatory system
X: Diseases of the respiratory system	XI: Diseases of the digestive system
XIV: Diseases of the genitourinary system	XVI: certain conditions originating in the perinatal period
XVII: Congenital malformations, deformations and chromosomal abnormalities	XIX: Injury, poisoning and certain other consequences of external causes

Table 9: Trend in life expectancy at birth by sex after elimination of a specific cause of death in Tamil Nadu (2003-2021)

	Male				Female			
	2003	2009	2015	2021	2003	2009	2015	2021
All Causes	69.1	70.7	72.1	79.8	74.1	75.5	76.4	85.9
I	70.6	71.7	73.0	80.9	76.0	76.3	77.2	86.9
II	69.7	71.2	72.5	80.2	74.9	76.1	76.9	86.5
IV	70.1	71.4	72.9	80.9	75.4	76.5	77.4	87.3
IX	81.7	84.4	89.1	98.2	90.3	92.2	95.2	108.4
X	71.1	72.1	73.3	82.6	76.7	77.0	77.6	88.3
XI	69.7	71.0	72.5	80.2	74.8	75.6	76.7	86.2
XIV	69.7	71.3	72.7	80.3	74.9	76.1	77.0	86.4
XVI	70.5	72.1	73.3	80.7	76.1	77.1	77.8	86.8
XVII	69.1	70.7	72.2	79.9	74.2	75.5	76.4	86.0
XIX	70.7	71.8	73.0	80.3	75.9	76.3	76.9	86.3

I: Certain infectious and parasitic diseases	II: Neoplasms
IV: Endocrine, nutritional and metabolic diseases	IX: Diseases of the circulatory system
X: Diseases of the respiratory system	XI: Diseases of the digestive system

XIV: Diseases of the genitourinary system	XVI: certain conditions originating in the perinatal period
XVII: Congenital malformations, deformations and chromosomal abnormalities	XIX: Injury, poisoning and certain other consequences of external causes

Between 2003 and 2021, life expectancy at birth in India and its selected states saw notable changes influenced by leading causes of death (Tables 4-9). The results provide insights into these trends, highlighting the impact of different diseases on life expectancy and the disparities between sexes. The decline in 2021 can be attributed to the COVID-19 pandemic, which led to a significant number of excess deaths. These shifts highlight the changing health landscape in India and the recent impact of the pandemic. Throughout the period, females consistently had a higher life expectancy at birth compared to males.

Trend in gain in life expectancy at birth during 2003-2021

Gain in life expectancy obtained by the difference between life expectancy values from the multiple decrement life tables and the corresponding cause-eliminated life tables for India and its selected states for the years 2003, 2009, 2015 and 2021 are shown in tables 10-15.

Table 10: Trend in gain in life expectancy at birth by sex after elimination of a specific cause of death, India (2003-2021)

	Male				Female			
	2003	2009	2015	2021	2003	2009	2015	2021
I	2.6	2.5	1.9	1.3	2.4	2.3	1.9	1.3
II	0.8	0.9	0.9	0.7	0.9	0.9	0.9	0.9
IV	0.8	0.9	0.7	1.0	1.1	1.0	0.7	1.3
IX	9.4	10.6	11.0	8.6	11.3	11.8	11.0	10.5
X	2.4	2.2	2.0	2.3	2.9	2.1	2.0	2.3
XI	0.9	0.8	0.8	0.6	0.5	0.4	0.8	0.4
XIV	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
XVI	1.8	1.7	1.4	1.1	2.4	1.8	1.4	1.2
XVII	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.1
XIX	1.6	1.1	1.0	0.8	1.3	0.8	1.0	0.5

I: Certain infectious and parasitic diseases	II: Neoplasms
IV: Endocrine, nutritional and metabolic diseases	IX: Diseases of the circulatory system
X: Diseases of the respiratory system	XI: Diseases of the digestive system
XIV: Diseases of the genitourinary system	XVI: certain conditions originating in the perinatal period
XVII: Congenital malformations, deformations and chromosomal abnormalities	XIX: Injury, poisoning and certain other consequences of external causes

Table 11: Trend in gain in life expectancy at birth by sex after elimination of a specific cause of death, Bihar (2003-2021)

	Male				Female			
	2003	2009	2015	2021	2003	2009	2015	2021
I	2.9	1.4	3.0	1.2	3.4	1.4	2.6	1.6
II	0.1	0.0	0.7	0.1	0.1	0.0	0.4	0.1
IV	0.2	0.2	0.9	0.1	0.3	0.2	0.8	0.1
IX	10.3	14.7	22.1	8.1	12.6	30.3	15.8	9.2
X	0.5	1.0	1.0	0.7	0.6	1.4	1.0	1.1
XI	0.2	1.1	1.0	0.3	0.2	0.9	0.7	0.3
XIV	0.3	0.4	1.2	2.9	0.4	0.3	1.0	3.2
XVI	2.4	1.7	2.2	0.5	1.5	1.9	3.2	0.6
XVII	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
XIX	2.2	0.6	0.7	0.2	2.6	0.8	0.8	0.4

I: Certain infectious and parasitic diseases	II: Neoplasms

IV: Endocrine, nutritional and metabolic diseases	IX: Diseases of the circulatory system
X: Diseases of the respiratory system	XI: Diseases of the digestive system
XIV: Diseases of the genitourinary system	XVI: certain conditions originating in the perinatal period
XVII: Congenital malformations, deformations and chromosomal abnormalities	XIX: Injury, poisoning and certain other consequences of external causes

Table 12: Trend in gain in life expectancy at birth by sex after elimination of a specific cause of death, Kerala (2003-2021)

	Male				Female			
	2003	2009	2015	2021	2003	2009	2015	2021
I	1.3	1.0	0.9	0.5	1.5	0.9	1.0	0.5
II	2.2	2.3	2.7	2.1	2.4	2.0	2.6	1.9
IV	1.2	1.5	1.6	2.0	1.5	1.7	2.6	3.1
IX	9.4	7.7	6.7	4.9	11.4	10.9	12.6	8.0
X	2.4	2.4	2.6	1.2	2.9	2.8	2.7	1.3
XI	0.8	1.0	1.3	1.0	0.8	0.6	0.8	0.6
XIV	0.7	0.4	0.6	0.4	0.8	0.4	0.7	0.4
XVI	0.4	0.5	0.5	0.7	0.7	0.6	0.5	0.2
XVII	0.0	0.0	0.3	0.5	0.0	0.1	0.3	0.2
XIX	1.0	0.7	0.9	0.6	0.9	0.6	0.5	0.4

I: Certain infectious and parasitic diseases	II: Neoplasms
IV: Endocrine, nutritional and metabolic diseases	IX: Diseases of the circulatory system
X: Diseases of the respiratory system	XI: Diseases of the digestive system
XIV: Diseases of the genitourinary system	XVI: certain conditions originating in the perinatal period
XVII: Congenital malformations, deformations and chromosomal abnormalities	XIX: Injury, poisoning and certain other consequences of external causes

Table 13: Trend in gain in life expectancy at birth by sex after elimination of a specific cause of death, Maharashtra (2003-2021)

	Male				Female			
	2003	2009	2015	2021	2003	2009	2015	2021
I	3.2	4.0	2.0	1.0	3.2	4.1	2.1	1.1
II	0.9	1.0	1.0	1.2	1.0	1.2	1.3	1.9
IV	0.7	0.6	0.6	2.1	0.7	0.8	0.7	3.1
IX	10.0	9.2	10.3	6.9	10.6	10.5	14.7	8.1
X	4.2	2.4	2.2	1.4	5.1	2.8	2.6	1.8
XI	0.9	0.8	0.6	0.8	0.8	0.3	0.3	0.4
XIV	0.6	0.6	0.6	0.4	0.7	0.6	0.7	0.5
XVI	1.2	0.7	0.6	0.5	2.1	1.0	0.7	0.5
XVII	0.4	0.1	0.1	0.1	0.7	0.2	0.1	0.1
XIX	2.2	1.4	1.1	0.7	2.2	1.0	0.4	0.2

I: Certain infectious and parasitic diseases	II: Neoplasms
IV: Endocrine, nutritional and metabolic diseases	IX: Diseases of the circulatory system
X: Diseases of the respiratory system	XI: Diseases of the digestive system
XIV: Diseases of the genitourinary system	XVI: certain conditions originating in the perinatal period
XVII: Congenital malformations, deformations and chromosomal abnormalities	XIX: Injury, poisoning and certain other consequences of external causes

Table 14: Trend in gain in life expectancy at birth by sex after elimination of a specific cause of death, Rajasthan (2003-2021)

	Male				Female			
	2003	2009	2015	2021	2003	2009	2015	2021
I	3.3	3.2	3.3	1.4	4.6	3.4	3.1	1.6
II	0.6	0.5	0.6	0.4	0.7	0.6	0.6	0.6
IV	0.4	0.9	0.5	0.3	0.6	1.3	0.8	0.6

IX	7.6	8.1	7.5	4.7	10.5	15.1	10.0	7.7
X	2.1	3.2	4.5	6.4	2.9	2.8	3.0	8.0
XI	0.9	0.6	0.7	0.6	1.2	0.3	0.5	0.5
XIV	0.6	0.2	0.6	0.4	0.9	0.4	0.6	0.5
XVI	2.7	2.4	2.6	1.9	2.2	3.5	2.6	1.6
XVII	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1
XIX	2.7	0.0	1.2	0.8	3.8	0.0	1.0	0.7

I: Certain infectious and parasitic diseases	II: Neoplasms
IV: Endocrine, nutritional and metabolic diseases	IX: Diseases of the circulatory system
X: Diseases of the respiratory system	XI: Diseases of the digestive system
XIV: Diseases of the genitourinary system	XVI: certain conditions originating in the perinatal period
XVII: Congenital malformations, deformations and chromosomal abnormalities	XIX: Injury, poisoning and certain other consequences of external causes

Table 15: Trend in gain in life expectancy at birth by sex after elimination of a specific cause of death, Tamil Nadu (2003-2021)

	Male				Female			
	2003	2009	2015	2021	2003	2009	2015	2021
I	1.6	1.0	0.8	1.1	1.9	0.9	0.8	1.0
II	0.7	0.5	0.4	0.5	0.8	0.7	0.5	0.5
IV	1.0	0.7	0.7	1.2	1.3	1.0	1.0	1.3
IX	12.6	13.7	16.9	18.4	16.2	16.7	18.8	22.5
X	2.0	1.4	1.2	2.8	2.6	1.6	1.1	2.4
XI	0.6	0.3	0.4	0.4	0.7	0.2	0.2	0.3
XIV	0.6	0.6	0.6	0.6	0.8	0.6	0.6	0.5
XVI	1.4	1.4	1.1	1.0	1.9	1.6	1.3	0.9
XVII	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1
XIX	1.7	1.1	0.8	0.6	1.8	0.8	0.5	0.4

I: Certain infectious and parasitic diseases	II: Neoplasms
IV: Endocrine, nutritional and metabolic diseases	IX: Diseases of the circulatory system
X: Diseases of the respiratory system	XI: Diseases of the digestive system
XIV: Diseases of the genitourinary system	XVI: certain conditions originating in the perinatal period
XVII: Congenital malformations, deformations and chromosomal abnormalities	XIX: Injury, poisoning and certain other consequences of external causes

In India, the gain in life expectancy at birth after eliminating each of the ten leading causes of death generally showed a rising trend for both males and females over the period from 2003 to 2021. An exception was observed in 2021 among males for diseases of the circulatory system, where the gain did not increase. Throughout the study period, the greatest increase in life expectancy at birth was consistently attributed to the elimination of diseases of the circulatory system for both sexes. Diseases of the circulatory system are among the leading causes of death in India. These diseases account for a significant proportion of premature mortality in both males and females. As a result, eliminating these causes has a substantial impact on increasing life expectancy. The reason the gain in life expectancy is highest when these diseases are removed is that they typically cause deaths at relatively younger ages compared to other causes that mostly affect the very elderly. Preventing or eliminating deaths from circulatory diseases means that many individuals survive well beyond ages at which they would have otherwise died, leading to a larger increase in the average expected lifespan.

Regarding the observed exception in 2021 for males, this year coincides with the onset of the COVID-19 pandemic, which heavily disrupted healthcare systems and affected mortality patterns. During 2021, deaths from circulatory diseases may have been underreported or masked by COVID-19

related deaths. Additionally, reduced access to healthcare and delayed treatment for cardiovascular conditions during the pandemic could have increased mortality from these diseases, offsetting potential gains in life expectancy from their elimination. This disruption likely explains why the gain in life expectancy for males from eliminating circulatory diseases did not increase as expected in 2021.

In Bihar, the maximum gain in life expectancy at birth is due to elimination of the diseases of the circulatory system in both male and female during the period under study.

Kerala's life expectancy at birth has shown a consistent upward trend. This indicates a general increase in life expectancy over the years, with a slight decline in 2021, possibly due to the impact of the COVID-19 pandemic. These statistics suggest that eliminating deaths due to diseases of the circulatory system could have a significant impact on increasing life expectancy.

In Maharashtra, Rajasthan and Tamil Nadu the maximum gain in life expectancy at birth is due to elimination of the diseases of the circulatory system in both male and female during the period under study and females are enjoying more life years as compared to males.

It is worth mentioning that males and females both are more burdened with diseases of the circulatory system. Thus, after elimination of circulatory disease, a female at birth could be expected to live more number of years longer than the actual life expectancy at birth. Favouring females in the potential gain in life expectancy at birth after elimination of the circulatory disease in India and its selected states during study period with exception of Bihar male in 2015.

DISCUSSION

The study estimated the gender difference in trend in life expectancy at birth and the trend in gain in life expectancy at birth after examining the potential improvements in life expectancy in India and its selected states after elimination of ten leading causes of death. The study found that during 2003-2021, life expectancy at birth in India and its selected states saw notable changes influenced by leading causes of death. Throughout the period, females consistently had a higher life expectancy at birth compared to males. The decline in 2021 can be attributed to the COVID-19 pandemic, which led to a significant number of excess deaths.

A study by Yadav et al.[30] has shown that India's life expectancy at birth dropped by 2.0 years in the pandemic year 2020 versus the non-pandemic year 2019. Muniyandi et al.[31] found that there was a decrease in life expectancy by 43 days (0.12 years) due to COVID−19 in India. Similar studies from developed countries reported that there was a decline in life expectancy in Canada by 0.41 years[32], in Italy by 0.5 years[33], and in Columbia by 0.18 years[33]. In India, Maharashtra was significantly affected by the COVID−19 pandemic and the impact on life expectancy at birth was estimated to reduce by 1.4 years[33]. Another study aiming to track the losses in life expectancy at birth globally found that Indians lost 2.6 years in their life expectancy due to the COVID-19 pandemic in the year 2021[34]. Another study estimated that India lost about 2.6 years of life expectancy between 2019 and 2020. The decline was more pronounced among females (3.1 years) than males (2.1 years)[35]. The study found that the biggest increase in gain in life expectancy for both males and females comes from eliminating diseases of the circulatory system (IX), rising substantially over the period. This confirms that circulatory diseases have a major impact on mortality. Gains from eliminating infectious diseases (I) and neoplasms (II) have decreased slightly over time in both sexes, possibly reflecting improvements in healthcare and control measures reducing their relative impact. Gains have increased for males but remained roughly stable for females, indicating sex-specific differences in digestive disease (XI) impact. Gains have decreased for both sexes in perinatal conditions (XVI), likely reflecting improved

maternal and neonatal care reducing deaths in early life stages. Notable decline in gains from eliminating injuries and external causes (XIX), especially for females, suggesting better safety and prevention efforts. Some causes such as genitourinary diseases (XIV), metabolic diseases (IV), respiratory diseases (X) and congenital malformations (XVII) show relatively low and stable impacts on life expectancy gains.

Circulatory diseases remain the key target for improving life expectancy. Their growing contribution to potential life expectancy gains suggests increasing mortality or slower progress in controlling these diseases compared to others. Decreases in gains from infectious diseases, neoplasms, perinatal conditions, and injuries indicate progress in public health, medical treatments, and preventive measures in India and its selected states. Females consistently show higher gains from eliminating circulatory diseases but lower gains from digestive diseases compared to males.

The study highlights the influence of each cause of death on the mortality scenario and ascertains the effect of causes of death on life expectancy in India and its selected states. The pattern of death by cause reflects the health status of the study population and in turn provides a rational basis for health planning.

The study findings are in line with findings of other studies. Jayachandran[36] found that gain in life expectancy at birth for males from respiratory disorders (cough) eliminated cause was 3.49 years but for females the cause was fever (3.21 years). Kulkarni et al.[37], found that net gain in life expectancy at birth in Goa was 11.5 years in males and 15.2 years in females after elimination of cardiovascular diseases. An ICMR study[38] found that diseases of the circulatory system were the most common cause of death in Maharashtra and Tamil Nadu. However, infectious and parasitic diseases were the most common cause of death in Assam, Bihar, and Rajasthan. A study found that gain in life expectancy at birth after elimination of diseases of the circulatory

system was 9.4 years in males and 11.3 years in females in India; 10.0/11.8 years in Maharashtra; and 7.6/11.6 years in Rajasthan[20]. Another study highlighted the gain in life expectancy at birth after elimination of mortality from diseases of the circulatory system (11.1 years in males and 13.1 years in females) in India[21]. In a study, it was established that elimination of diseases of the circulatory system yield the maximum gain in life expectancy at birth in males (14.64 years) and in females (15.49 years) in Haryana[22].

Between 2003 and 2021, India experienced significant changes in gain in life expectancy at birth after elimination of specific diseases with notable variations across its selected states and between sexes. These trends highlight the overall improvements in life expectancy in India, with significant progress in female life expectancy. However, the COVID-19 pandemic in 2020-2021 led to a temporary decline.

It may kindly be noted that these ten leading causes of deaths *viz.*, diseases of the circulatory system (32.1%); diseases of the respiratory system (10%); certain infectious and parasitic diseases (7.1%); endocrine, nutritional and metabolic diseases (5.8%); injury, poisoning and certain other consequences of external causes (5.6%); neoplasms (4.7%); certain conditions originating in the perinatal period (4.1%): diseases of the digestive system (3.4%); diseases of the genitourinary system (3.3%); and congenital malformations, deformations and chromosomal abnormalities (0.5%) constituted around 76.6% of the total medical certified deaths in 2020. There were 18,11,688 medically certified deaths (22.5%) in 2020, in the total registered deaths of 80,62,070 in India and this pertains to urban area only[24]. As per census 2011, around 70% (68.84%) population lives in rural areas[39]. If we take into consideration the same percentage of the total medically certified deaths and calculate the number of deaths under these ten leading causes of deaths we would have a substantial number of deaths to be averted after eliminating these causes.

LIMITATION

The study used secondary data for mortality analysis by routine death registration without verbal autopsy procedures, so it is limited by the quality of data. Furthermore, the cause-eliminated life table analysis was a tool for analyzing which might be overestimated because these estimates fail to take into account the fact that those who are saved from one cause are likely to have another condition, which may increase their risks of dying.

CONCLUSION

Between 2003 and 2021, India and its selected states experienced notable changes in life expectancy. Throughout this period, females consistently had a higher life expectancy at birth than males. The decline observed in 2021 can be attributed to the COVID-19 pandemic, which resulted in a substantial number of excess deaths. During these years, India also saw significant variations in the gains in life expectancy at birth following the elimination of specific diseases, with differences observed across its selected states and between sexes. Overall, these trends reflect considerable improvements in life expectancy in India, particularly among females, although the pandemic in 2020–2021 caused a temporary setback.

Circulatory diseases remain a key priority for improving life expectancy. Their growing contribution to potential life expectancy gains indicates either increasing mortality or slower progress in controlling these diseases compared to others. The main risk factors for circulatory diseases are strongly influenced by lifestyle factors, particularly behavioural and dietary habits. These findings have important implications for practical decision-making, including the setting of health goals, resource allocation, and the design of targeted health programmes. Although the assumption of complete elimination of certain causes of death is not realistic, it remains a useful analytical approach for understanding the relative impact of competing risks.

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